LIBRARY
BUREAU OF COMMERCIAL FISHERIES
U. S. FISH AND WILDLIFE SERVICE
P. O. BOX 3830
HONOLULU 12, HAWAII

PERIODICAL
HL
PUBLICATIONS
1961

DATE OF MAGAZINE	BORROWER'S NAME	TIME DUE
3/1/65	Thomas A Manar	
~~4/3/81~~	~~M Seki~~	

PERIODICAL
HL
PUBLICATIONS
1961

LIBRARY
BUREAU OF COMMERCIAL FISHERIES
U. S. FISH AND WILDLIFE SERVICE
P. O. BOX 3830
HONOLULU 12, HAWAII

HL
Publications

3120

1961

1961 HL Publications

Barkley, Richard A. and Thomas S. Austin
Distribution of properties above the Equatorial Undercurrent. /Abstract/ Tenth Pacific Science Congress of the Pacific Science Association, Honolulu, Hawaii, 1961, Abstract of Symposium Papers, p. 339-340.

Craig, William and Joseph J. Graham
Report on a co-operative, preseason survey of the fishing grounds for albacore (*Thunnus germo*) in the eastern north Pacific, 1959. California Fish and Game, vol. 47, no. 1, p. 73-85.

Graham, Joseph J. and James W. McGary
Investigation of the potential albacore resource of the central North Pacific. U. S. Fish and Wildlife Service, Commercial Fisheries Review, vol. 23, no. 11, p. 1-7. (Also as Separate no. 631)

__________ and William L. Craig
Oceanographic observations made during a cooperative survey of albacore (*Thunnus germo*) off the North American west coast in 1959. U. S. Fish and Wildlife Service, Special Scientific Report--Fisheries no. 386, 31 p.

Grice, George D.
Calanoid copepods from equatorial waters of the Pacific Ocean. U. S. Fish and Wildlife Service, Fishery Bulletin 186, vol. 61, p. 171-246.

McGary, James W., Joseph J. Graham and Tamio Otsu
Oceanography and North Pacific albacore. California Cooperative Oceanic Fisheries Investigations Reports, vol. 8, p. 45-53.

Mann, Herbert J.
Underwater observation chambers on the research vessel "Charles H. Gilbert." *IN* Jan-Olof Traung and Norio Fujinami, Research Vessel Design, FAO Research Vessel Forum in Tokyo September 18-30, 1961. P. MAN 1-9.

Marr, John C.
Note on the recovery rate of tagged skipjack, *Katsuwonus pelamis*, and the effects of handling. *IN* International Commission for the Northwest Atlantic Fisheries, North Atlantic Fish Marking Symposium, Woods Hole, Mass., May 1961, Contribution no. 1, 2 p.
(See 1963 for final publication)

__________ and Lucian M. Sprague
The use of blood group characteristics in studying subpopulations of fishes. *IN* International Commission for the Northwest Atlantic Fisheries, North Atlantic Fish Marking Symposium, Woods Hole, Mass., May 1961, Contribution no. 50, 9 p. (See 1963 for final publication)

Matsumoto, Walter M.
Collection and descriptions of juvenile tunas from the central Pacific. Deep-Sea Research, vol. 8, no. 3-4, p. 279-285.

Nakamura, Eugene L. and Heeny S. H. Yuen
Incidence of the giant trematode, *Hirudinella marina* Garcin, in skipjack tuna, *Euthynnus pelamis* (Linnaeus), from Marquesan and Hawaiian waters. Transactions of the American Fisheries Society, vol. 90, no. 4, p. 419-423.

Riffenburgh, Robert H.
A system analysis of the marine ecology. Bulletin of the International Statistical Institute, vol. 38, part III, p. 57-66.

Sherman, Kenneth
Occurrence of early developmental stages of the oblong ocean sunfish Ranzania laevis (Pennant) in the central North Pacific. Copeia, no. 4, p. 467-470.

__________ and Robert P. Brown
Oceanographic and biological data, Hawaiian waters, January--October 1959. U. S. Fish and Wildlife Service, Special Scientific Report--Fisheries no. 396, 71 p.

Shippen, Herbert H.
Distribution and abundance of skipjack in the Hawaii Fishery, 1952-53. U. S. Fish and Wildlife Service, Fishery Bulletin 188, vol. 61, p. 281-300.

Sprague, Lucian M.
Erythrocyte antigens of the oceanic skipjack (*Katsuwonus pelamis*) recognized by phytoagglutinis. /Abstract/ Records of the Genetics Society of America, no. 30, p. 111. (Also in Genetics, vol. 46, no. 8, p. 901.

__________ and Leslie I. Nakashima
Studies on the erythrocyte antigens of the skipjack tuna (*Katsuwonus pelamis*). /Abstract/ Tenth Pacific Science Congress of the Pacific Science Association, Honolulu, Hawaii, 1961. Abstracts of Symposium Papers, p. 186.

Strasburg, Donald W.
Diving behaviour of Hawaiian skipjack tuna. Journal du Conseil Permanent International pour l'Exploration de la Mer, vol. 26, no. 2, p. 223-229.

____
Review of living fishes of the world, by Earl S. Herald, Atlantic Naturalist, Octbober-December 1961, p. 266.

Digitized by the Internet Archive
in 2025

https://archive.org/details/hl-publications_1961_1

Strasburg, Donald W.
Larval carapid fishes from Hawaii, with remarks on the ecology of adults. Copeia, no. 4, p. 478-480.

__________ and John C. Marr
Banded color phases of two pelagic fishes, *Coryphaena hippurus* and *Katsuwonus pelamis*. Copeia, no. 2, p. 226-228.

Uchida, Richard N.
Hermaphroditic skipjack. Pacific Science, vol. 15, no. 2. p. 294-296.

Yuen, Heeny S. H.
Bow wave riding of dolphins. Science, vol. 134, no. 3484, p. 1011-1012.

Publications not included in this volume

Bureau of Commercial Fisheries, Biological Laboratory, Honolulu, Hawaii
Progress in 1960. U.S. Fish and Wildlife Service, Circular 127, 31 p.

Marr, John C.
A hypothesis of the population biology of the sardine, *Sardinops caerulea*. [Abstract] Proceedings of the Ninth Pacific Science Congress, vol. 10, p. 63.

Sherman, Kenneth
A high school oceanographic laboratory. American Biology Teacher, vol. 23, no. 1, p. 29-35.

________, and John P. Wise
Incidence of the cod parasite *Lernaeocera branchialis* L. in the New England area, and its possible use as an indicator of cod populations. Limnology and Oceanography, vol. 6, no. 1, p. 61-67.

DISPLAY COPY

Abstracts of Symposium Papers, Tenth Pacific Science Congress. p. 339-340.

SYMPOSIUM ON EQUATORIAL CIRCULATION
IN THE PACIFIC

Distribution of Properties about the Equatorial Undercurrent

RICHARD A. BARKLEY and THOMAS S. AUSTIN, Bureau of Commercial Fisheries Biological Laboratory, Honolulu, Hawaii, U.S.A.

The DOLPHIN expedition, carried out in connection with the IGY in 1958, was a joint undertaking of the Scripps Institution of Oceanography and the Bureau of Commercial Fisheries Biological Laboratory, Honolulu, to study the Equatorial Undercurrent (Cromwell Current) by means of standard oceanographic techniques and direct current measurements.

Sections are given showing the distribution of salinity, temperature, and dissolved oxygen along 140°W. between 4°N. and 4°S. and along the Equator from 140°W. to the Galapagos Islands. The significant features of these sections are related to the currents and water-mass properties. North-south asymmetry in the distribution of both salinity and oxygen are attributed to the sources of water entering the Undercurrent. An analysis of the internal pressure distribution (relative to that at 1,000 m.) shows that a zonal pressure gradient exists above 600 m. along the Equator which tends to accelerate the eastward flow between 140°W. and about 114°W.; from 114°W. to about 97°W. there is little evidence of any zonal pressure gradient, while to the east of 97°W. the gradient is reversed and would tend to decelerate an eastward-moving current. The effects of these gradients on the Equatorial Undercurrent, and the resulting distribution of properties, are discussed.

DISPLAY COPY

REPRINT FROM

CALIFORNIA FISH and GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

VOLUME 47 JANUARY, 1961 NUMBER 1

REPORT ON A CO-OPERATIVE, PRESEASON SURVEY OF THE FISHING GROUNDS FOR ALBACORE *(THUNNUS GERMO)* IN THE EASTERN NORTH PACIFIC, 1959[1]

WILLIAM L. CRAIG
Marine Resources Operations, California Department of Fish and Game; and

JOSEPH J. GRAHAM
Honolulu Biological Laboratory, U.S. Bureau of Commercial Fisheries, Honolulu, Hawaii

INTRODUCTION

Since about 1942, the northeastern Pacific albacore fishery has been worth an average of $6,000,000 annually to California fishermen alone. This, plus its value to the remainder of the Pacific coast fishing industry, places albacore among our most important fishery resources. Albacore landings are generally surpassed in weight by several other fishes, but in dollar value they consistently maintain a position among the top three commercial species. This high value is attributed to two factors: harvest of the domestic supply is limited by the seasonal nature of the fishery, and demand is high because superior packing qualities make albacore the only species that may be labeled "whitemeat tuna." Albacore are not only important for the livelihood of commercial fishermen, but as a highly prized gamefish, they provide recreation for thousands of sportfishermen principally along the California coast.

Albacore range throughout the north Pacific Ocean and are fished principally by Americans (east) and Japanese (middle and west). The relationship of the fisheries in the eastern, middle and western Pacific was cloaked in mystery for many years, but recent tag returns have indicated they may well be supported by a single population (Clemens, ms). Tagging also has demonstrated the same seasonal movements that catch records had indicated for many years (Clemens, 1955). Briefly, these movements may be summarized as: northward at least along the California coast during the summer and fall and westward across the Pacific toward Japan during the winter.

Little is known of the migration route into the eastern Pacific fishery except that it takes place sometime during spring. The location of early season concentrations of fish varies considerably, and annually presents a challenge to the fisherman as to where he should commence fishing. At times, fishermen have found it necessary to scout thousands of square miles of the sea along 300 miles or more of coastline. For several seasons prior to 1957 the first catches were located well to the south of Guadalupe Island, Mexico. Since that time the early concentrations occurred at varying distances to the north of the island.

---

[1] Submitted for publication June, 1960.

In order to learn more about the route of the spring migration and to assist the industry in opening the season earlier, the California Department of Fish and Game for several years has fielded an exploratory survey of the offshore fishing grounds prior to the regular season. A cruise such as this was planned for the month of June 1959. The Honolulu Biological Laboratory, U.S. Bureau of Commercial Fisheries, was contemplating a similar survey of the west coast fishing grounds during the same period. Since the desired results were identical, final plans were made for a co-operative survey. Participation of two vessels promised far greater coverage of the area and collection of an increased amount of oceanographic data that might be useful in predicting future occurrences of albacore.

This report describes the fishing methods and resulting catch related to sea surface temperature for the cruises of both agencies. Another report will summarize the combined oceanographic observations (Graham and Craig, ms).

VESSELS AND INTINERARY

Assigned to the survey were the *N. B. Scofield* (Cruise 59S4) from the California Department of Fish and Game and the *Hugh M. Smith* (Cruise 52) from the Honolulu Biological Laboratory. The two vessels explored the offshore waters along 600 miles of the North American coastline from the latitude of Point San Eugenia, Baja California to the latitude of San Francisco.

The offshore waters of central and southern California were chosen for the *N. B. Scofield* survey from June 1 through June 25, 1959. The actual survey consisted of a series of lines running roughly northwest and southeast between the Mexican boundary and San Francisco and offshore as far as long. 128° W. (Figure 1).

The *Hugh M. Smith* survey was conducted south of the *N. B. Scofield,* primarily off the coast of northern Baja California, Mexico, and east of long. 125° W. The vessel sailed from Honolulu on April 28, 1959, first occupying a series of preliminary fishing and oceanographic stations between Honolulu and the mainland. The cruise terminated in San Diego on June 19, 1959 (Figure 1). An unscheduled interruption in the early portion of the survey was necessitated by the illness of a crew member who was taken to San Francisco for treatment.

FISHING GEAR AND METHODS

Trolling lines, longlines and gill nets were used in attempting to locate albacore schools. Live anchovies were carried for hook and line fishing, but actually were used only occasionally to chum the jig lines. Both vessels were equipped with similar fishing gear except that the *N. B. Scofield* carried no longlines.

The Honolulu Biological Laboratory cruise plan emphasized occupying a series of predetermined longline and gill net stations, with trolling between these stations. The Department of Fish and Game plan emphasized trolling, with the use of gill nets secondary.

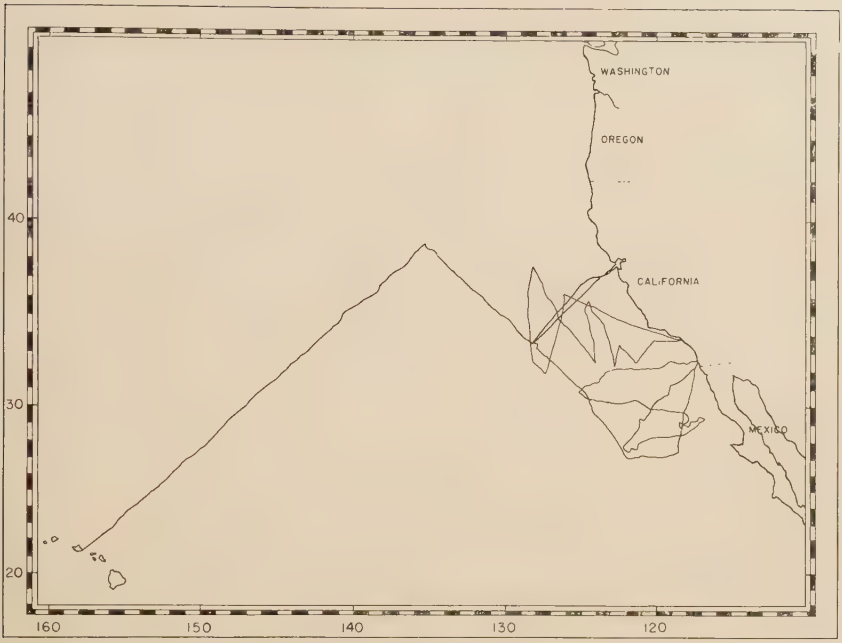


FIGURE 1. A portion of the eastern north Pacific Ocean illustrating schematically vessel tracks for the *N. B. Scofield* (Cruise 59S4) and *Hugh M. Smith* (Cruise 52) albacore survey, 1959.

Trolling Gear

The trolling gear was basically the same as that used by the commercial fleet (Scofield, 1956). Feathered japheads and bone jigs outfitted with barbless hooks were used on lines of varying length. Seven lines were trolled from the *N. B. Scofield.* These were arranged with a 20- and 15-fathom line on each outrigger pole and 7-, 9-, and 11-fathom lines fishing from the stern. The *Hugh M. Smith* trolled eight lines, two from each outrigger pole and four from the stern. Line lengths were alternately 15 and 30 fathoms (Figure 2).

Trolling was done during daylight at speeds ranging from 4 to 10 knots, but averaging six to seven.

Gill Nets

Both vessels were equipped with 10 shackles of nylon mesh gill net constructed by the Honolulu Biological Laboratory (Graham and Mann, 1959). Each shackle, 50 fathoms long by 4 deep, consisted of mesh sizes varying from 4½ to 7½ inches stretched measure. When setting from the vessel, shackles were arranged as follows: 4½″(1), 7½″(2), 6½″(4), 7½″(2) and 5½″(1).

Gill nets were set at dusk, the process requiring 30 to 60 minutes. Hauling took place at dawn the following day and required about one hour. The nets were set from the stern and hauled from the bow of the *N. B. Scofield,* and were both set and hauled from the bow of the *Hugh M. Smith.*

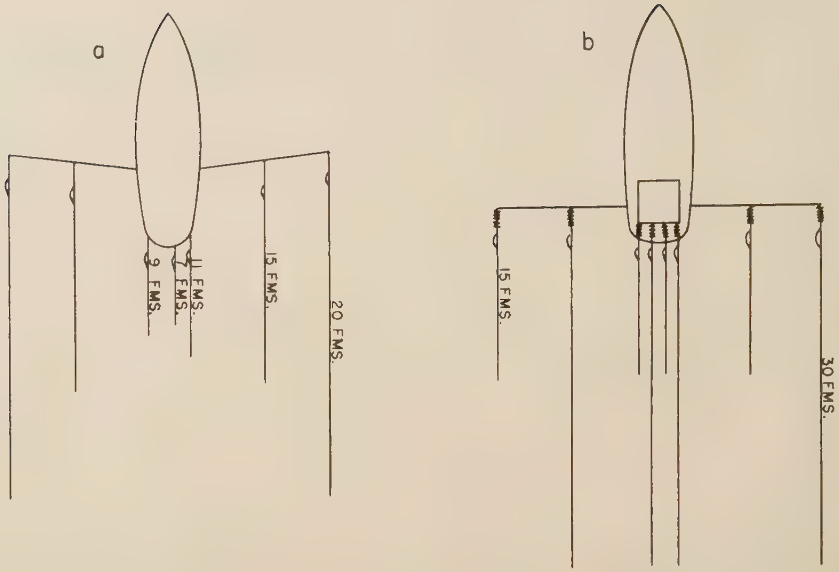


FIGURE 2. Arrangement and length of trolling lines on the *N. B. Scofield* (a) and *Hugh M. Smith* (b) albacore survey, 1959.

Longlines

Longlines used by the *Hugh M. Smith* were a modification of the gear originally developed at the Honolulu Biological Laboratory (Mann, 1955). Twenty baskets (210 fathoms per basket) of gear were fished at each longline station. The 12 droppers of a single basket were of varied length and in a set were arranged in three identical series as follows: 8, 2, 16, and 4 fathoms (Figure 3). Each dropper was buoyed separately to allow for a reasonably accurate estimate of the depth of capture.

Longlines were fished during daylight, usually from 0800 to 1400 hours. The gear required about 30 to 40 minutes to set and from 60 to 90 minutes to haul.

RESULTS OF FISHING

Trolling Catch

Of the three types of gear, trolling produced the only albacore catches. In all, 314 albacore were caught on trolling gear and of these, 207 were tagged and released (Table 1).

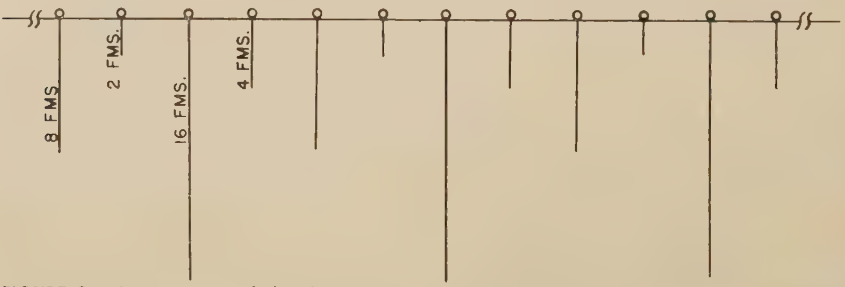


FIGURE 3. Arrangement of the droppers in a single basket (210 fathoms) of longline gear used on the *Hugh M. Smith* albacore survey, 1959.

TABLE 1

Troll Catches for the N. B. SCOFIELD (Cruise 59S4) and HUGH M. SMITH (Cruise 52), Albacore Survey, 1959

Date of catch	Position		Species	Number caught	Number tagged	Surface temperature degrees F.
	N. lat.	W. long.				
N. B. SCOFIELD						
6/ 5/59	34°46′	122°25′	Albacore	1	0	59.0
	34°47′	122°28′	Albacore	10	6	59.0
	34°49′	122°33′	Albacore	2	1	59.0
	34°52′	122°38′	Albacore	3	2	59.0
	34°56′	122°49′	Albacore	10	9	59.4
	34°59′	122°54′	Albacore	11	6	59.0
	35°01′	122°57′	Albacore	3	1	59.0
6/ 6/59	35°42′	124°45′	Albacore	1	1	59.4
6/ 7/59	35°50′	125°59′	Albacore	2	1	60.1
	34°50′	126°06′	Albacore	8	5	61.0
6/ 8/59	34°39′	126°16′	Albacore	5	5	61.0
	34°20′	126°22′	Albacore	1	0	60.3
	34°15′	126°23′	Albacore	7	3	60.6
	34°10′	126°26′	Albacore	2	1	60.6
6/12/59	36°31′	128°23′	Albacore	1	0	60.8
	36°39′	128°22′	Albacore	3	3	60.8
	36°45′	128°19′	Albacore	1	0	60.8
6/13/59	37°07′	128°18′	Albacore	1	0	61.0
	37°30′	128°06′	Albacore	3	2	61.0
	36°56′	127°38′	Albacore	2	1	60.4
6/15/59	35°24′	126°32′	Albacore	1	0	60.8
	34°48′	126°04′	Albacore	2	1	61.2
	34°34′	125°51′	Albacore	13	8	61.3
	34°25′	125°43′	Albacore	3	1	61.5
6/16/59	33°54′	125°12′	Albacore	1	1	60.4
	33°40′	125°00′	Albacore	37	22	61.2
	33°38′	124°58′	Albacore	4	3	60.6
	33°17′	124°40′	Albacore	5	3	60.6
6/17/59	32°34′	123°58′	Albacore	1	1	61.7
6/18/59	33°08′	124°06′	Albacore	2	2	59.5
	33°11′	124°07′	Albacore	3	3	59.5
	33°13′	124°09′	Albacore	5	3	59.5
	33°18′	124°09′	Albacore	7	5	59.4
	33°19′	124°09′	Albacore	8	7	59.5
	33°21′	124°10′	Albacore	6	3	59.5
	33°26′	124°11′	Albacore	2	1	59.7
	33°31′	124°14′	Albacore	3	1	59.7
	33°33′	124°14′	Albacore	2	0	59.7
	33°35′	124°15′	Albacore	1	1	59.7
	33°38′	124°15′	Albacore	5	3	60.3
	33°39′	124°17′	Albacore	6	3	60.3
	33°46′	124°18′	Albacore	24	18	60.4
	33°51′	124°20′	Albacore	3	1	60.3
6/19/59	33°37′	124°30′	Albacore	1	1	60.4
	33°49′	124°28′	Albacore	5	2	60.4
	34°02′	124°24′	Albacore	3	2	60.1
	34°28′	124°29′	Albacore	2	2	60.8
6/19/59	34°43′	124°33′	Albacore	5	4	60.3
6/20/59	34°47′	124°34′	Albacore	1	1	60.4
	34°53′	124°36′	Albacore	1	1	59.7

TABLE 1—Continued

Troll Catches for the N. B. SCOFIELD (Cruise 59S4) and HUGH M. SMITH (Cruise 52), Albacore Survey, 1959

Date of catch	Position		Species	Number caught	Number tagged	Surface temperature degrees F.
	N. lat.	W. long.				
	34°57′	124°37′	Albacore	4	3	61.0
	35°00′	124°38′	Albacore	4	4	60.8
	35°02′	124°38′	Albacore	1	1	60.8
6/21/59	35°20′	123°51′	Albacore	1	0	60.1
6/22/59	33°38′	123°04′	Albacore	1	1	59.9
	33°32′	123°02′	Albacore	1	1	60.6
	33°29′	123°01′	Albacore	10	6	60.4
	33°25′	123°00′	Albacore	8	5	59.9
	33°23′	122°59′	Albacore	3	1	58.6
	33°17′	122°57′	Albacore	2	2	58.8
6/23/59	32°20′	122°44′	Albacore	5	3	61.3
	32°25′	122°43′	Albacore	6	5	61.3
	32°26′	122°40′	Albacore	4	4	61.3
	33°05′	122°32′	Albacore	2	0	61.2
	33°12′	122°31′	Albacore	2	1	60.8
	33°15′	122°30′	Albacore	4	4	60.6
	33°25′	122°28′	Albacore	3	2	61.0
6/24/59	32°45′	121°30′	Albacore	2	2	61.0
	32°41′	121°28′	Albacore	2	2	61.2
	32°37′	121°26′	Albacore	5	5	61.2
	32°33′	121°22′	Albacore	3	2	61.0
H. M. SMITH						
4/29/59	23°29′	155°07′	Dolphin	1	0	73.0
5/ 3/59	33°09′	143°00′	Skipjack	2	2	63.9
5/ 9/59	36°44′	132°26′	Albacore	2	2	60.8
6/13/59	27°26′	121°49′	Skipjack	1	0	64.8

The *Hugh M. Smith* traveled approximately 6,000 miles during the 53 days of the cruise. This mileage was divided almost equally between the survey area, east of long. 125° W., and the preliminary route from Honolulu to this area. Lines were trolled for approximately 1,900 miles in the primary survey area and over 1,500 miles enroute, and 13 gill net and nine longline sets were made (Figure 4). Two albacore were caught on trolling lines and tagged some 500 miles west of San Francisco. Three skipjack *(Katsuwonus pelamis)* and a single dolphin *(Coryphaena hippurus)* were the only other fish caught on this gear.

The *N. B. Scofield* traveled approximately 2,400 miles during the 25-day cruise. Lines were trolled for about two-thirds of this distance and in addition a single gill net set was made (Figure 5). The first schools of albacore were encountered between 90 and 120 miles west by north of Point Arguello early in the cruise. Subsequently, 312 were caught of which 205 were tagged and released at numerous localities. Severe northwesterly weather conditions prevailing throughout the northern survey area hampered fishing in most areas. No other species of fish was caught by the *N. B. Scofield* on trolling lines.

Gill Net Catch

Of 13 gill net stations occupied by the *Hugh M. Smith,* all but three were in the primary survey area. The first set was made on May 4, and the last on June 18. All were made in water ranging from 57.5 to 65.8 degrees F. at the surface. No albacore were netted. Six other kinds of fish were caught, including: skipjack, Pacific bonito *(Sarda chiliensis),* pomfrets, blue shark *(Prionace glauca)* and bonito shark *(Isurus glaucus)* (Table 2). A set was made on May 9, near where two albacore

TABLE 2
Gill Net Sets Made by the N. B. SCOFIELD (Cruise 59S4) and HUGH M. SMITH (Cruise 52), Albacore Survey, 1959

Date of set	Position		Species	Number caught	Surface temperature degrees F.
	N. lat.	W. long.			
N. B. SCOFIELD					
6/11/59	35°35′	128°28′	No catch		61.2
HUGH M. SMITH					
5/ 4/59	34°48′	140°41′	Bonito shark	1	62.1
			Pomfret	25	
5/ 7/59	38°48′	135°06′	Blue shark	4	57.5
			Pomfret	7	
5/ 9/59	36°39′	132°24′	Blue shark	1	61.2
			Pomfret	2	
5/22/59	26°59′	121°59′	Skipjack	6	65.0
5/23/59	27°00′	120°56′	No catch		65.8
5/24/59	27°00′	119°31′	No catch		65.5
5/30/59	32°30′	118°20′	Blue shark	4	62.1
			Bonito shark	1	
5/31/59	32°08′	119°35′	Blue shark	3	60.0
6/ 4/59	30°28′	123°35′	No catch		62.2
6/ 9/59	28°50′	117°57′	Dolphin	1	64.5
6/10/59	29°23′	117°00′	Bonito shark	1	63.5
6/13/59	27°33′	122°15′	Pomfret	1	64.8
6/18/59	31°59′	117°46′	Pacific bonito	4	65.4
			Blue shark	4	
			Bonito shark	1	

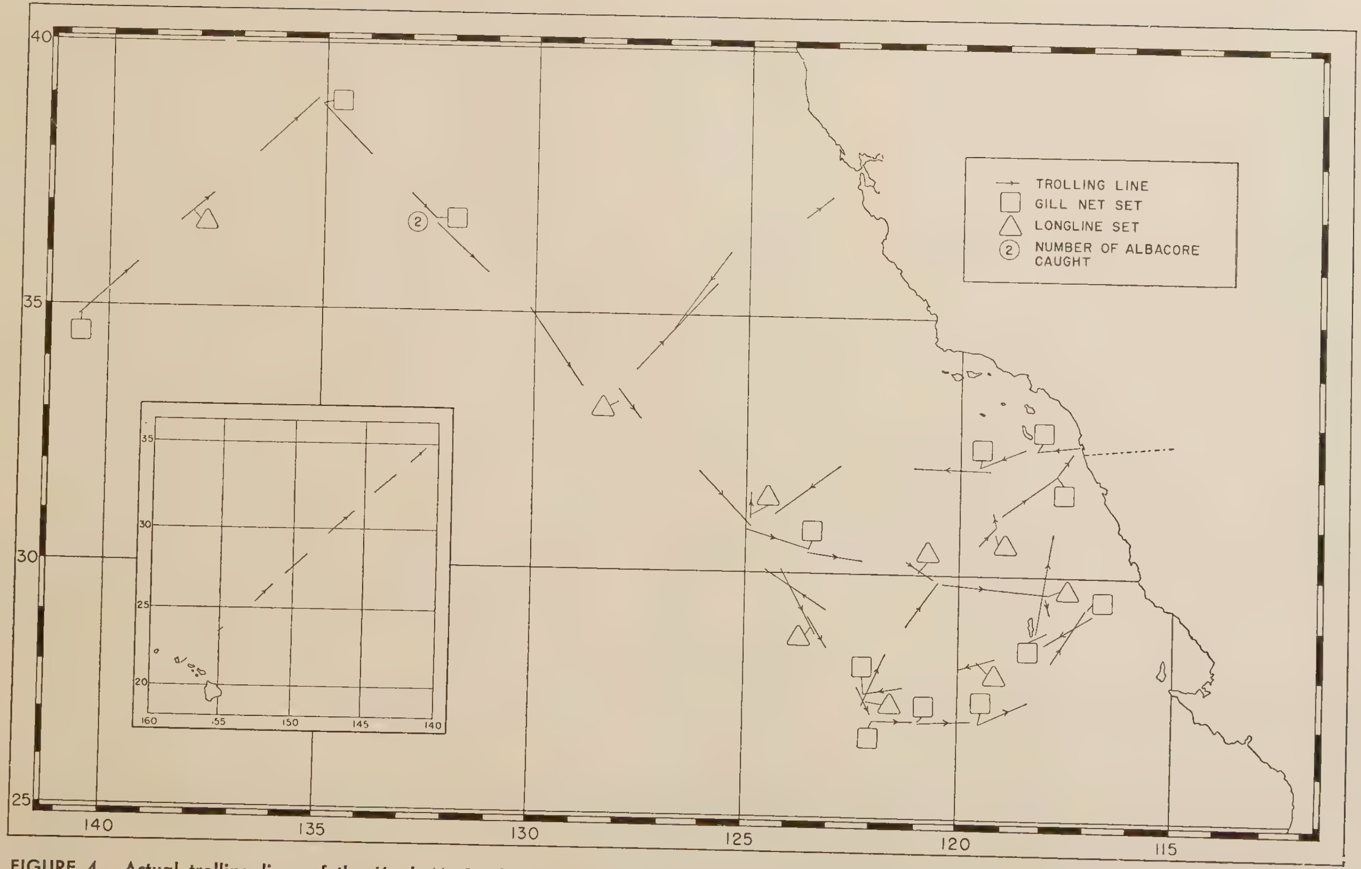

TROLLING LINE
GILL NET SET
LONGLINE SET
② NUMBER OF ALBACORE CAUGHT
②
40
35
30
25
140
135
130
125
120
115
35
30
25
20
160
155
150
145
140

FIGURE 4. Actual trolling lines of the *Hugh M. Smith* showing relative position of gill net and longline sets and the location of albacore catches. Inset shows trolling lines between Honolulu and long. 140° W.

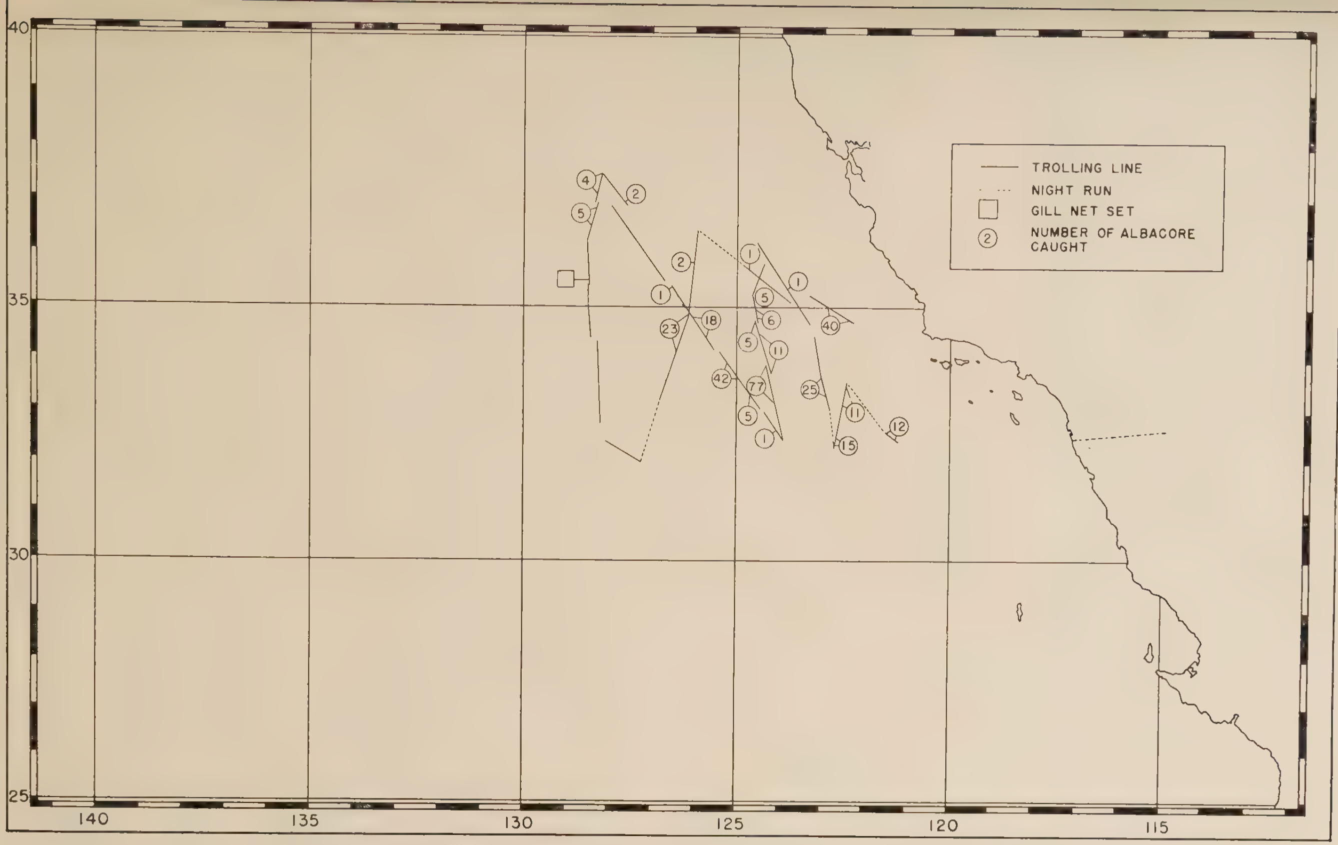

TROLLING LINE
NIGHT RUN
GILL NET SET
NUMBER OF ALBACORE CAUGHT
40
35
30
25
140
135
130
125
120
115
4
2
5
2
1
1
1
5
6
40
23
18
5
11
42
77
25
11
12
5
1
15

FIGURE 5. Actual trolling lines of the *N. B. Scofield* showing location of albacore catches and the relative position of the single gill net set.

had been caught on trolling lines, but only blue sharks and pomfrets were caught.

A single gill net set from the *N. B. Scofield,* approximately 390 miles west by north of Point Arguello on June 11, in 61.2-degree F. water, caught no fish.

Longline Catch

The first of nine longline stations occupied by the *Hugh M. Smith* was on May 6, and the last on June 17. All but two were in the primary survey area. Surface temperatures at the longline stations ranged from 60.9 to 64.7 degrees F. No albacore were caught, but three other kinds of fish including: bigeye tuna *(Parathunnus sibi),* hammerhead sharks (*Sphyrna* sp.) and blue sharks were taken (Table 3). The *N. B. Scofield* did not use this gear.

TABLE 3

Longline Sets Made by the HUGH M. SMITH (Cruise 52), Albacore Survey, 1959

Date of set	Position		Species	Number caught	Surface temperature degrees F.
	N. lat.	W. long.			
5/ 6/59	36°48′	138°05′	Blue shark	4	61.3
5/17/59	33°19′	128°01′	Blue shark	2	60.9
5/21/59	28°56′	123°27′	No catch		63.8
5/22/59	27°23′	122°09′	No catch		64.7
6/ 3/59	31°07′	124°56′	Blue shark	1	61.7
6/ 6/59	30°03′	120°58′	Blue shark	3	61.9
6/ 8/59	29°38′	117°55′	Bigeye tuna	2	63.6
			Blue shark	6	
			Hammerhead shark	1	
6/12/59	28°15′	119°34′	Blue shark	1	64.1
6/17/59	30°47′	119°10′	Blue shark	4	62.5
			Hammerhead shark	1	

SIZE RANGE OF THE ALBACORE CATCH

Based upon a frequency distribution of 199 albacore tagged by the *N. B. Scofield* (Table 4), over 80 percent of the catch was within the size range 630 to 680 mm. fork length (approximately 11 to 14 pounds). Lengths of untagged fish were similar and none was outside of the above size range. Weights recorded for the two albacore tagged from the *Hugh M. Smith* were 8 and 12 pounds, well within the overall size distribution.

SEA SURFACE TEMPERATURES AND ALBACORE OCCURRENCES

Rather comprehensive records of sea surface temperature were maintained aboard both vessels. In general, surface temperatures within 50 miles of shore varied from 54 degrees F. around Santa Rosa and San Miguel Islands to over 70 degrees F. along the immediate southern California coast and within a few hundred miles of the Hawaiian Islands. Offshore in the actual survey areas the range was between 57 and 65 degrees F.

Surface temperature records were sufficiently detailed to make it possible to construct rough isotherms within the survey area. Plotting

TABLE 4

Lengths of 199 Albacore Tagged from the N. B. SCOFIELD, Albacore Survey, 1959

Length (cm.)	Frequency	Percent	Length (cm.)	Frequency	Percent
56	1	0.5	67	25	12.6
57	0	--	68	15	7.5
58	1	0.5	69	8	4.0
59	2	1.0	70	0	--
60	1	0.5	71	0	--
61	2	1.0	72	1	0.5
62	7	3.5	73	1	0.5
63	15	7.6	74	1	0.5
64	36	18.1	75	0	--
65	48	24.1	--	--	--
66	34	17.1	81	1	0.5

albacore occurrences on a chart of these isotherms shows the relationship of the catches to surface temperature (Figure 6).

Ninety-eight percent of the albacore caught were from the rather restricted temperature range of 59.0 to 61.3 degrees F. (15.0 to 16.3 degrees C.). The remaining two percent were caught within plus or minus 0.4 degrees F. from these extremes (Table 5). Though surface temperatures where albacore occurred during May and June 1959 tended toward the lower extreme, they were predominantly within the range of 60 to 69 degrees F. from which California fishermen reported over 90 percent of their catch during the period 1955 through 1957.

TABLE 5

Albacore Troll Catches by Temperature, Albacore Survey, 1959

Temperature		Catch		Temperature		Catch	
Degrees C.	Degrees F.	Number	Percent	Degrees C.	Degrees F.	Number	Percent
14.8	58.6	3	0.96	15.8	60.4	44	14.01
14.9	58.8	2	0.64	15.9	60.6	23	7.32
15.0	59.0	30	9.55	16.0	60.8	17	5.41
15.1	59.2	0	0.00	16.1	61.0	29	9.23
15.2	59.4	18	5.73	16.2	61.2	48	15.29
15.3	59.5	24	7.64	16.3	61.3	28	8.92
15.4	59.7	9	2.87	16.4	61.5	3	0.96
15.5	59.9	9	2.87	16.5	61.7	1	0.32
15.6	60.1	6	1.91				
15.7	60.3	20	6.37	Total		314	100.00

SUMMARY

1. In an attempt to obtain an early opening for the 1959 season and to learn the route of the spring migration of albacore a joint, preseason survey of the fishing grounds was carried out by the California Department of Fish and Game and the Honolulu Biological Laboratory, U.S. Bureau of Commercial Fisheries.

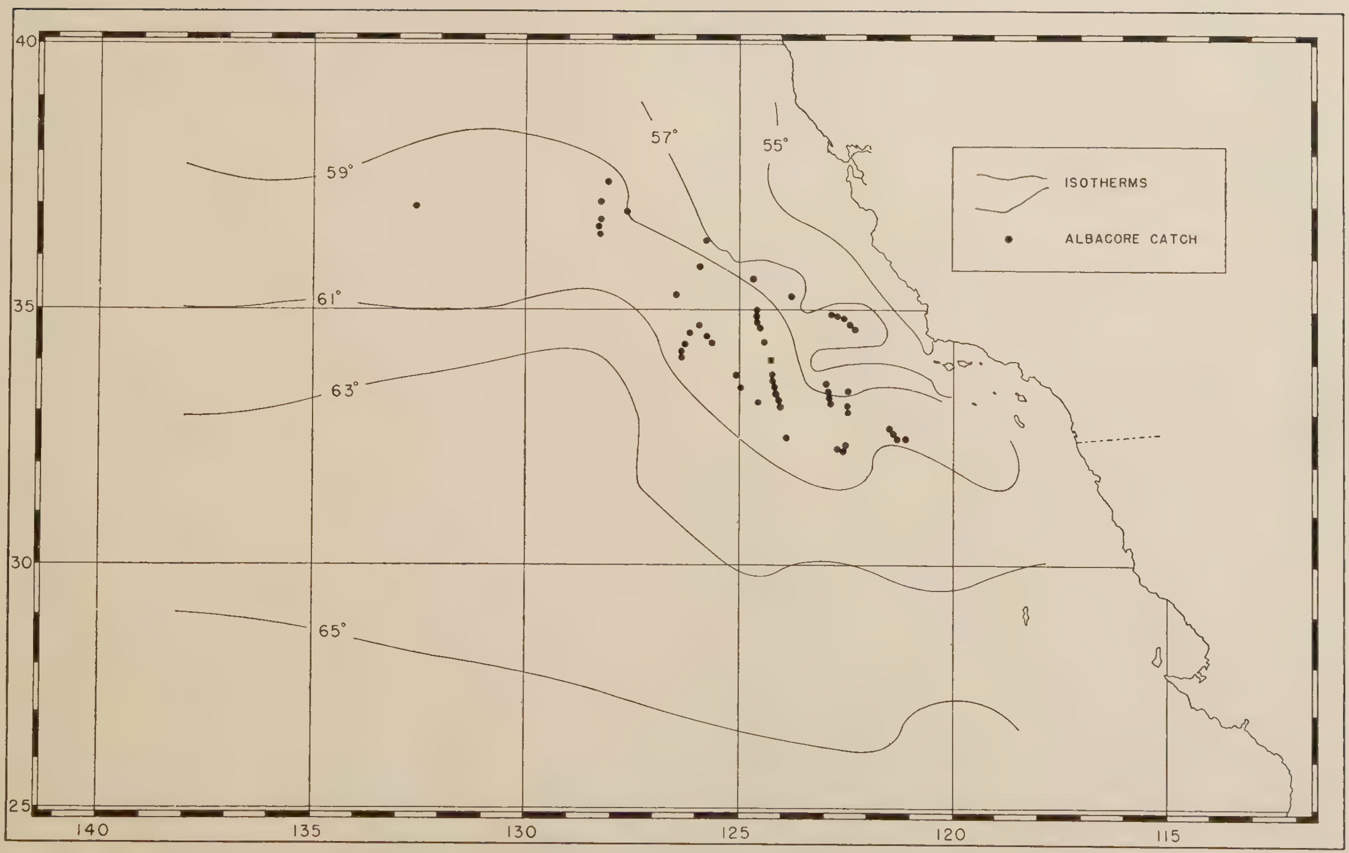

ISOTHERMS
ALBACORE CATCH
55°
57°
59°
61°
63°
65°
40
35
30
25
140
135
130
125
120
115

FIGURE 6. Albacore catch locations related to surface isotherms, by two degree F. intervals, as interpreted from sea surface temperature data collected during the 1959 survey.

2. The California Department of Fish and Game vessel *N. B. Scofield* surveyed the offshore fishing grounds north of Lat. 32° N. from June 1 through June 25, 1959. The Bureau of Commercial Fisheries vessel *Hugh M. Smith* surveyed to the south of Lat. 32° N. from April 28 through June 19, 1959.
3. Fishing gear consisted of feather and bone jigs, longlines and gill nets.
4. Trolling north of Lat. 32° N. produced the only catches of albacore. Of 314 caught trolling, 207 were tagged and released.
5. Fourteen gill net sets and nine longline sets caught no albacore. These two types of gear did produce small catches of bigeye tuna, skipjack, Pacific bonito, pomfrets, dolphin, blue shark, bonito shark and hammerhead shark.
6. The predominant size group of albacore caught was from approximately 11 to 14 pounds.
7. Offshore sea surface temperatures ranged from about 57 to 65 degrees F. Albacore occurrences were limited to a range between 58.6 and 61.7 degrees F.

ACKNOWLEDGMENTS

The authors wish to extend their gratitude to the captains and crews on the *N. B. Scofield* and the *Hugh M. Smith*. Without their splendid support, often under trying conditions, the data presented in this paper could not have been obtained.

LITERATURE CITED

Clemens, Harold B.
1955. Catch localities for the Pacific albacore *(Thunnus germo)* landed in California, 1951 through 1953. Calif. Dept. Fish and Game, Fish Bull. 100, 28 pp.

Clemens, Harold B.
n.d. Migration and growth of the Pacific albacore *(Thunnus germo)*. Calif. Dept. Fish and Game, Mar. Res. Oper. Manuscript.

Graham, Joseph J., and William L. Craig
n.d. Oceanographic observations made during a 1959 albacore *(Thunnus germo)* survey off the North American west coast. U. S. Bur. Comm. Fish., Honolulu Biol. Lab. Manuscript, 1960. (To be published in Spec. Sci. Rept.: Fish. Series.)

Graham, Joseph J., and Herbert J. Mann
1959. Construction and catch selectivity of albacore gill nets used in the central north Pacific. U. S. Fish and Wildl. Serv., Comm. Fish. Rev., vol. 21, no. 8, pp. 1-6.

Mann, Herbert J.
1955. Construction details of improved tuna longline gear used by P.O.F.I. U. S. Fish and Wildl. Serv., Comm. Fish. Rev., vol. 17, no. 12, pp. 1-10.

Scofield, W. L.
1956. Trolling gear in California. Calif. Dept. Fish and Game, Fish Bull. 103, 45 pp.

o

printed in CALIFORNIA STATE PRINTING OFFICE
33014 1-61 200

DISPLAY COPY

COMMERCIAL FISHERIES REVIEW

November 1961 Washington 25, D. C. Vol. 23, No. 11

INVESTIGATION OF THE POTENTIAL ALBACORE RESOURCE OF THE CENTRAL NORTH PACIFIC

By Joseph J. Graham,* and James W. McGary**

CONTENTS

	Page
Introduction	1
The Plan	2
The Commercial Test	3
An Environmental Difference	5
Summary	7
Literature Cited	7

ABSTRACT

A study of the albacore tuna resources in the central and eastern North Pacific by exploratory fishing of a research and a chartered vessel of the U. S. Bureau of Commercial Fisheries Laboratory, Honolulu, culminated in a commercial-scale test. The test was made with gill nets in the central North Pacific during July and August 1958. The catches obtained from the chartered vessel Paragon showed that summer gill-netting for albacore in the central North Pacific was not commercially feasible. However, environmental conditions encountered in 1958 were not similar to those in 1955 and 1956 when the exploratory catches, which prompted the test, were made. Colder surface water was present during 1958, and as a result, there was a southward shift of surface temperatures and a corresponding shift in albacore distribution. An instance of unusual albacore behavior was also observed which might have been related to the environment and have affected the efficiency of the gill net fished from the Paragon. It is suggested that one vessel on a single cruise does not provide an adequate test of the potential albacore fishery in the area.

INTRODUCTION

In 1954 the U. S. Bureau of Commercial Fisheries Biological Laboratory at Honolulu, Hawaii, received an allotment of funds from the Saltonstall-Kennedy Act (68 Stat. 376) to study the albacore tuna, Thunnus germo (Lacepede),[1] in the central and eastern North Pacific. One of the major objectives of this study was to determine whether commercially profitable concentrations of albacore tuna were present in the mid-ocean area between the Japanese fishery in the western North Pacific and the United States fishery along the west coast of North America. A series of exploratory fishing and oceanographic cruises was made in the area between 170° E. longitude and the United States west coast. This phase of the study culminated in a commercial-scale test of albacore fishing in the mid-ocean area during July and August of 1958.

The series of cruises leading up to the commercial test provided information on the seasonal distribution and relative abundance of albacore (Graham MS.)[2]. The results may be summarized as follows. In the fall, there was an almost continuous distribution of albacore

---

*Fishery Research Biologist
**Oceanographer
} Formerly of the Fishery Biological Laboratory, U. S. Bureau of Commercial Fisheries, Honolulu, Hawaii.
Note: Present address of senior author: Bureau's Biological Laboratory, Galveston, Tex.
" " " junior " : Office of Naval Research, Department of Navy, Washington, D. C.

[1] Also known as Germo alalunga (Bonnaterre), Thunnus alalunga (Gmelin), and Germo germo (Lacepede).
[2] Graham, Joseph J. MS. "The macroecology of the albacore tuna, Thunnus germo (Lacepede), in the central North Pacific."

U. S. DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
SEP. NO. 631

across the North Pacific between the Japanese and the American west coast fisheries. This same area was to a large extent devoid of fish in the winter. During the spring, albacore were present between the two fisheries, but their distribution was discontinuous, and they were difficult to find in abundance. A concentration of albacore was located in the summer around the mid-forty latitudes between 175° W. and 160° W. longitude south of the Aleutian Island chain. East of 160° W., fish were scarce until the vicinity of the west coast of North America was reached.

The discovery of the summer concentration of fish in the central North Pacific came about primarily through the use of surface gill nets. Surface trolling lines, the major gear used in the American west coast fishery, were only of secondary importance (Tester 1956, Anonymous 1956, Graham 1957, and Graham and Mann 1959). It appeared that this area contained albacore which could be exploited commercially, because (1) the concentration of fish was located in the same area during two consecutive summers, 1955 and 1956; (2) in 1956, within the area of concentration, good catches were persistent locally for a period of 2 to 3 days; and (3) the fish captured were mostly of a size acceptable for canning (10 to 28 pounds).

THE PLAN

These findings warranted a practical test with gill nets by commercial fishermen. It was decided to engage a chartered vessel, with a guaranteed return to the fishermen. This arrangement allowed us to take advantage of the knowledge we had gained and insured an adequate test of the area. It also provided freedom of operation in order to take advantage of the skills and knowledge of the fishermen and simulated as nearly as possible a commercial fishing operation. The bid specifications were prepared with these features in mind.

The general area delimited for fishing encompassed all positions where promising catches had been made during the 1955-56 summer cruises (41° N. to 48° N. latitude, and 175° W. to 155° W. longitude). Locations of the individual gill-net sets were left to the discretion of the master of the vessel. Each prospective bidder was provided with background material summarizing previous catch data for the area.

The successful bidder was required to equip his vessel so that a minimum of 40 shackles of gill-netting could be set. The construction of the shackles was to be based in part on a study by Graham and Mann (1959) on the results of previous gill-net fishing conducted by the Honolulu Laboratory. The mesh was to measure between 7½ and 8½ inches (stretched measure) which would allow the escape of small fish. The minimum length of each shackle was to be 50 fathoms and its depth 5 fathoms. To obtain full payment of the contract price, the vessel was to set 1,200 shackles between July 20 and September 10, 1958, or as an alternative, catch at least 60 tons of albacore. All sets were to be made during evening twilight and allowed to soak at least 6 hours before being retrieved. In addition to fishing gill nets, a minimum of 6 surface lines were to be trolled during all daylight runs within the fishing area and at least 3 lines on runs to and from the fishing area.

The Bureau's research vessel Hugh M. Smith was to make oceanographic and biological observations in the fishing area, on conditions usually associated with the presence or absence of albacore. These observations were to be compared with those of previous summer cruises (1955 and 1956) and to assist the contract vessel by delineating the distribution of albacore. Albacore were to be sampled in the surface layer by using: (1) 10 shackles of gill net with mesh sizes of 4½ to 7½ inches; (2) 5 trolling lines; and (3) 20 baskets of a specially designed long line with 12 droppers per basket and with each hook suspended from a buoy. Droppers were placed 15 fathoms apart along the continuous mainline and were grouped in series of 3 each with 4 lengths, 2, 4, 8, and 12 fathoms. The gill net was set at twilight and allowed to fish overnight. Lines were trolled on daylight runs between stations and when patrolling long-line sets, which were made primarily in the morning hours. A more complete description of the fishing methods employed aboard the Hugh M. Smith and the contract vessel is presented elsewhere (McGary and Graham 1960).

THE COMMERCIAL TEST

Northwestern Fisheries Inc. of Seattle, Wash., submitted the low bid of $45,990 for their vessel the M/V Paragon, a 90-foot (over-all) halibut schooner with a beam of 19 feet and a 9-foot draft (empty). Her cruising and maximum speeds were $10\frac{1}{2}$ and 11 knots, respectively. The ability of the vessel to fish gill nets under the summer weather conditions of the central North Pacific had been proven during previous salmon research cruises fielded by the Bureau's Seattle Exploratory Fishing Station (Powell and Peterson 1957).

Fig. 1 - Crew of the Paragon. One crew member is not shown here.

The M/V Paragon departed from Ballard, Wash., on July 16 with a master, a crew of four fishermen (fig. 1), and one of our Laboratory's biologists aboard.

The first gill-net set from the Paragon was made on July 26 at 41° 40' N., 157° 11' W. (fig. 2), and resulted in a promising catch of 145 albacore (2,800 pounds). Two subsequent sets in the same vicinity yielded successively smaller catches of 133 fish (2,000 pounds) and 119 fish (1,900 pounds). Compared to the first 3 sets, the second group of 3 catches in this vicinity was drastically reduced and declined steadily to a low of 13 fish (200 pounds). The Paragon then explored northward and westward to 163° 37' W., without any significant improvement in catch. Meanwhile, gill nets were set from the Hugh M. Smith for the first time on July 29; five sets were made along 160° W. (fig. 3) in about the same latitudes as the sets made by the M/V Paragon. Only 4 and 5 albacore each were caught in two of the sets; none in the other three sets.

As a result of these poor catches, the efforts of the two vessels were coordinated in an attempt to locate albacore in abundance. It was decided to explore and compare catches made in western and eastern portions of the area. Therefore, after the completion of work along 160° W., the Hugh M. Smith's cruise plan was altered, and instead of working along 165° W. the vessel turned westward to 175° W. The M/V Paragon returned eastward. The numbers of fish caught per set from both vessels varied considerably (figs. 2 and 3). The one relatively good catch of 49 albacore in the 10 shackles of gill net fished from the Hugh M. Smith was offset by the fact that about one-half of these fish weighed less than 10 pounds each. As pointed out above, fish less than 10 pounds were purposely excluded from the Paragon's catch by the large gill-net meshes ($7\frac{1}{2}$ to $8\frac{1}{2}$ inches).

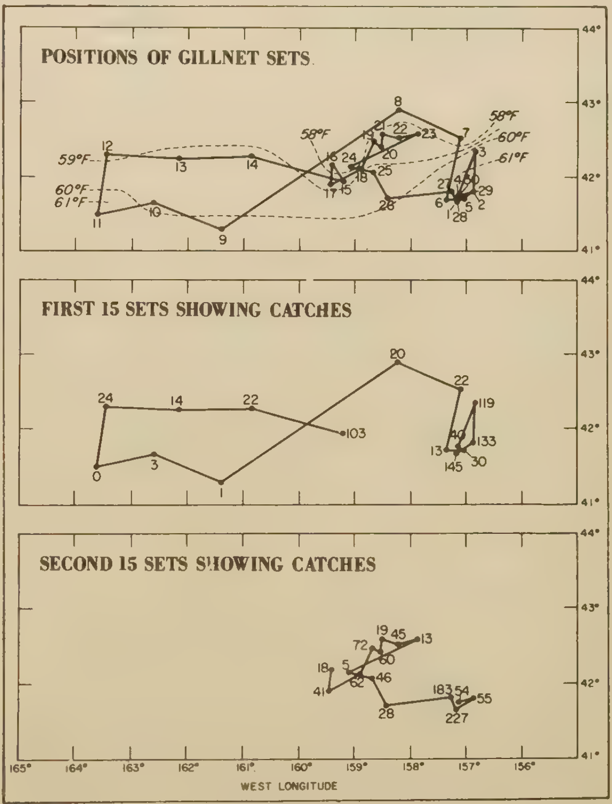

POSITIONS OF GILLNET SETS
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
58°F
59°F
60°F
61°F
FIRST 15 SETS SHOWING CATCHES
0 3 1 24 14 22 103 20 22 119 40 133 13 145 30
SECOND 15 SETS SHOWING CATCHES
18 41 5 62 72 19 45 13 60 46 28 183 54 55 227
44°
43°
42°
41°
165° 164° 163° 162° 161° 160° 159° 158° 157° 156°
WEST LONGITUDE

Fig. 2 - Vessel tracks, sets, and catches of the M/V Paragon.

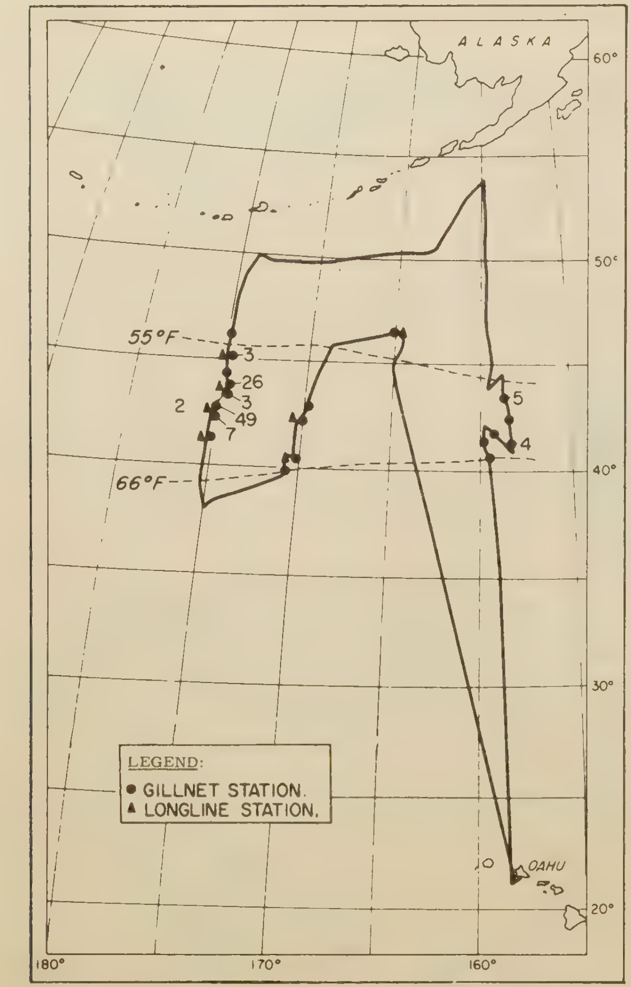


Fig. 3 - Vessel tracks, sets, and catches of Hugh M. Smith.

The master of the Paragon considered these results and elected to remain in the vicinity of 158° W. (fig. 2), where he judged that the fishing, while not good, showed some promise. Unfortunately, this promise was not fulfilled, and the Paragon then returned to the vicinity of her first set. There, 2 good catches of about 2,800 pounds (183 fish) and 3,400 pounds (227 fish) were made in 4 sets. The catches made from the Paragon and those from the Hugh M. Smith, which in the meantime had explored as far west as 170° W. and found no commercial quantities of albacore, did not indicate to the master of the former vessel that it would be profitable to continue fishing beyond the contract period, so he departed the fishing area for Seattle on August 30. The Hugh M. Smith was scheduled to remain in the area to continue fishing and to make oceanographic observations along 165° W. longitude. However, the serious illness of a fisherman forced the captain to discontinue the cruise on September 2, and the vessel returned to Honolulu (fig. 3).

A summary of the catch statistics shows that 1,617 albacore were caught from the Paragon by gill nets and 234 fish by trolling; of the latter number, 212 were caught in the area of gill-netting. The weight of the catch unloaded from the Paragon at Seattle was 27,053 pounds. This weight was made up of individual fish ranging in size from $6\frac{1}{2}$ to 46 pounds. Three size groups were present: $6\frac{1}{2}$-10 pounds, 10-21 pounds, and 21-46 pounds. (A total of 781 albacore were measured by the biologist aboard the Paragon.) Approximately 92 percent of the fish were desirable commercially (i.e., each greater than 10 pounds), and of those, fish between 15 and 17 pounds accounted for 49 percent or almost one-half of the catch. Ninety-seven albacore were caught by the Hugh M. Smith with gill nets, 13 on troll lines, and 2 on long-line gear. Measurements of 107 showed a similar size range ($6\frac{1}{2}$-35 pounds) and the same size groups as were found in the catch made from the Paragon. One difference in the size composition of the fish obtained from the two vessels was evident. As would be expected because of the smaller meshes ($4\frac{1}{2}$ - $6\frac{1}{2}$ inches) used from the Hugh M. Smith, a relatively large number (41 percent of the total catch) of albacore smaller than 10 pounds were captured. However, among the remaining fish of commercially desirable sizes, fish between 15 and 17 pounds represented 29 percent of the total catch.

On the basis of effort, the gill-net catch rate and the trolling catch rate from the Paragon were higher than from the Hugh M. Smith. The catch per shackle per set from the Paragon ranged from 0 to 5.7, with an average of 1.3; the catch rate from the Hugh M. Smith ranged from 0 to 4.9, with an average of 0.5. On a catch-per-hour basis in the fishing area, the troll catch rates from the Paragon varied from 0.0 to 7.4 per hour for individual days, with an average of 1.1. The

Table 1 - Summary of Expenses and Proceeds from the M/V Paragon Albacore Venture

Expenses:	$
Salaries	5,548.30
Fuel	1,742.00
Food	1,344.29
Gear1/.	4,553.95
Total	13,188.54
Proceeds from the sale of albacore	4,800.00

1/Only one-third of the total cost of the gill net ($13,406) and trolling gear ($85.28) has been entered. It is assumed that with a reasonable amount of repair both could be used for at least two additional trips.

rates from the Hugh M. Smith were much lower; 0.0 to 0.5 per hour, with an average of only 0.06.

The $13\frac{1}{2}$ tons of albacore captured from the Paragon were far below the 60 tons anticipated from the results of previous summer surveys (1955 and 1956). The weight of the catch after a storage period of 3 months was approximately 24,000 pounds; it was sold for 20 cents a pound for a total of $4,800. The degree to which this particular test of the potential albacore fishery of the area was a financial failure is evident from the cost and proceeds statistics of table 1.

AN ENVIRONMENTAL DIFFERENCE

The failure of the albacore catch by the Paragon to live up to expectations appears to be related to a difference between the oceanic environments which existed during the summers of the previous surveys (1955 and 1956), on the one hand, and that which prevailed during the summer of the test (1958), on the other. The oceanic circulation in the fishing area is largely zonal (east-west), and only slight seasonal and annual shifts occur in the location of the boundaries of the major water types (McGary et al. 1958). However, a major change in the physical characteristics of the area does occur in the form of large seasonal fluctuations in surface

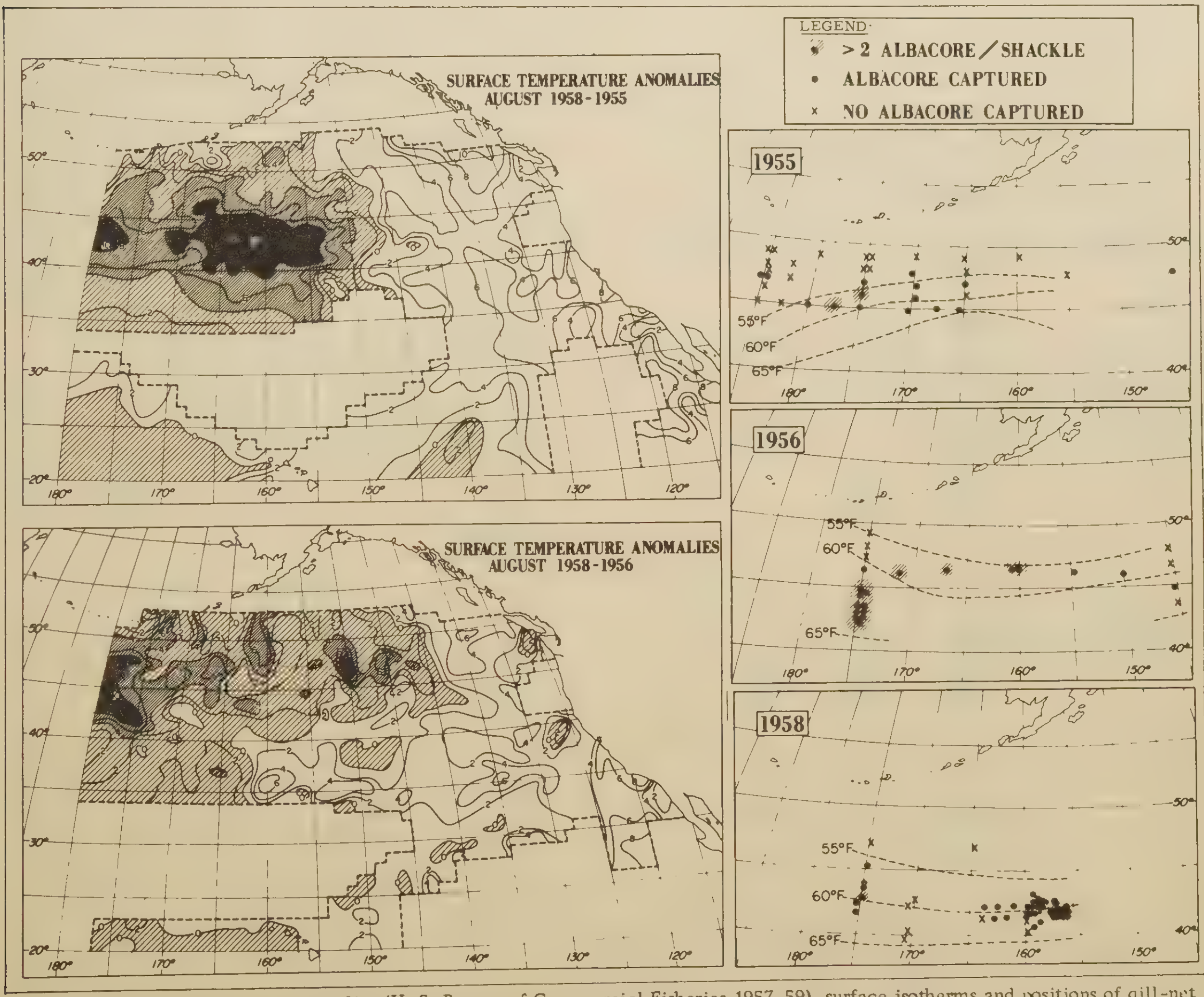

SURFACE TEMPERATURE ANOMALIES AUGUST 1958-1955
SURFACE TEMPERATURE ANOMALIES AUGUST 1958-1956
LEGEND
> 2 ALBACORE / SHACKLE
ALBACORE CAPTURED
NO ALBACORE CAPTURED
1955
1956
1958
55°F
60°F
65°F
50°
40°
30°
20°
180°
170°
160°
150°
140°
130°
120°

Fig. 4 - Surface temperature anomalies (U. S. Bureau of Commercial Fisheries 1957-59), surface isotherms and positions of gill-net catches of albacore during the summers of 1955, 1956 and 1958. The 1955 gill net catches were obtained from Powell and Peterson (1957), and isotherms and the 1956 and 1958 catches from the Honolulu Laboratory. Hatching indicates areas colder in 1958 than in 1955 and 1956.

temperature. Also, local annual differences in surface temperature can be considerable for a given year, and such a change occurred during the summer of 1958.

Sea-surface temperatures observed from the Hugh M. Smith and M/V Paragon in the summer of 1958 were as much as 8° to 10° F. colder in some parts of the fishing area than those obtained during the summer cruises of 1955 and 1956. These colder temperatures represented either (1) differences in seasonal warming (which were not as great in 1958) or (2) the influx of a water mass having inherently different temperature characteristics. However, the thickness of the surface layer above the thermocline (50-150 feet) was approximately the same in 1958 as during the previous years, discounting the second possibility.

Charts in figure 4 show the August 11-20 anomalies or departures of local surface temperatures in 1955 and 1956 from those of 1958. Lines are drawn through points of equal departure at intervals of 2° F. Where the lines enclose an area colder in 1958 than in 1955 and 1956, it is hatched, the amount of hatching depending upon the degree of coldness. The anomaly charts are accompanied by plots of surface isotherms and gill-net catches made during the 3 years concerned. In the 1958-55 chart, the entire area west of 140° W. longitude, from about 35° N. to 50° N. latitude, is shown as colder in 1958 than in 1955. The greatest differences appear as areas of 10°-12° F. colder water occurring in the vicinity of 44° N. to the west of 155° W. The magnitude of such differences is more evident when it is realized that they approach the average annual seasonal variation of 15° F. The 1958-56 chart shows a similar distribution in that the surface waters over the area north of 40° N. were colder in 1958 than in 1956. These differences are reflected in the distribution of surface isotherms shown for the 3 years in figure 4. During 1955 and 1956 the surface isotherms, which encompass the range of surface temperature usually coincident with albacore distribution in the central North Pacific (Graham 1957, Powell and Peterson 1957, and Graham MS.[2]), are to be found approximately 3 degrees of latitude farther north than in 1958. The albacore gill-net catches, although they did not cover the area very well, suggest that the southward shift in isotherms during 1958 was accompanied by a corresponding shift in albacore distribution.

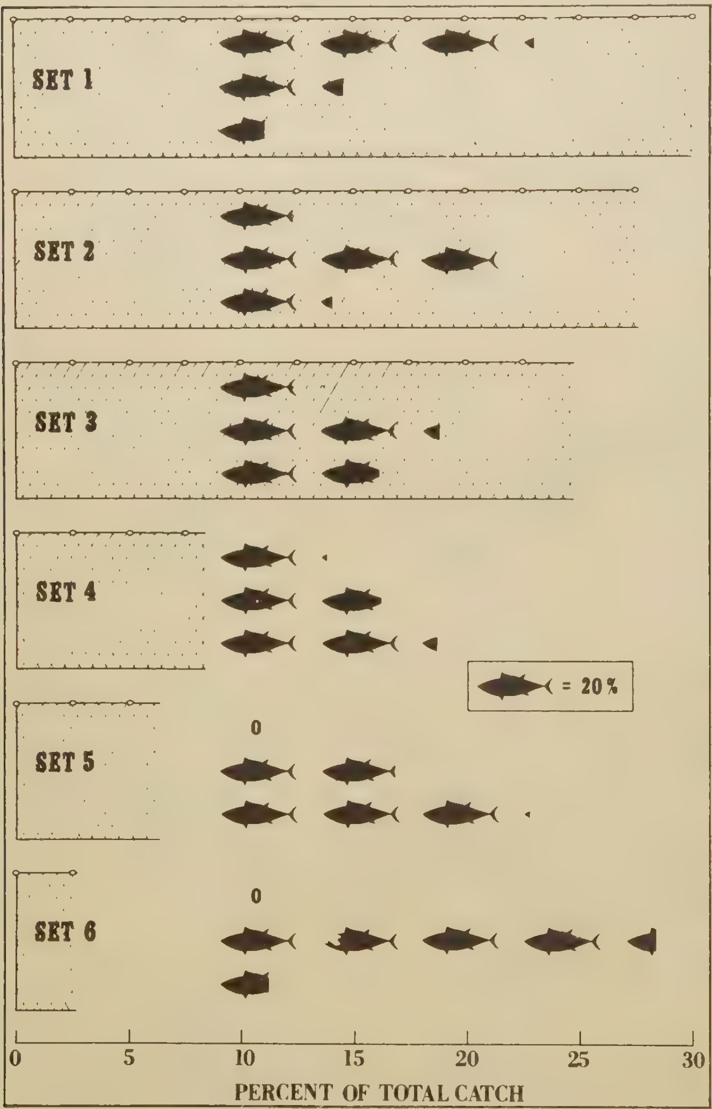


Fig. 5 - Percentage of total catch (480) from the first six gill-net sets and the percentage (per set) of the fish observed in the top, middle, and bottom of the net. The length of the net simulates the percentage of the total catch and the number of fish represents the percentage captured in that position of the net. A total of 393 observations was made concerning the position of fish in the net.

It is difficult to directly associate this environmental difference with the years of successful and unsuccessful gill-netting. However, one instance of unusual behavior exhibited by the albacore deserves mention because of its possible relation to the environment and its bearing on the efficiency of the *Paragon's* gill nets. Analysis of the depth positions of albacore caught in the *Paragon's* net at her first six stations (fig. 5), when the catch dropped from 1$\frac{1}{2}$ tons to almost nothing, showed a progressive increase in the catch percentiles of the bottom and middle two-thirds of the net[3]. Possibly the albacore progressively went below the 30-foot depth of the net in search of forage which was generally low according to surface night-light counts of saury and squid from the *Paragon* (McGary and Graham 1960). Whether or not this represented a general decrease of albacore forage in the fishing area during 1958 as compared to 1955 and 1956 cannot be ascertained.

---

[2] See footnote 2 on p. 1.

In conclusion, the annual variability in the oceanic environment and in the distribution of albacore is so great that the operation of a single vessel on a single cruise is not an adequate test of the commercial fishing potentiality of the area investigated.

SUMMARY

Exploratory fishing by the U. S. Bureau of Commercial Fisheries Biological Laboratory at Honolulu during a study of the albacore tuna resources in the central and eastern North Pacific, resulted in plans for a commercial-scale test. This test was directed toward a mid-ocean, summer concentration of albacore susceptible to harvest with gill nets. A contract was made with owners of the M/V *Paragon* of Seattle, Wash., to conduct a commercial trial in the area during July and August 1958 using commercial gill nets.

The catches from the *Paragon* showed that summer gill-netting for albacore tuna in the central North Pacific was not commercially feasible. However, environmental conditions encountered in 1958 were not similar to those in 1955 and 1956 when the exploratory catches, which prompted the test, were made. Colder surface water was present during 1958, and as a result there was a southward shift of surface temperatures and a corresponding shift in the albacore distribution. In addition, one vessel probably does not provide an adequate test of the potential albacore fishery in the area.

An instance of unusual albacore behavior was also observed which might have been related to the environment and have affected the efficiency of the gill net fished from the *Paragon*. An analysis of six consecutive gill-net sets within a single area showed a progressive decrease in catch. The pattern of the fish in the nets indicated that the decrease was caused by the albacore progressively decending below the 30-foot depth of the net. Night-light observations suggested the possibility that the descent was related to a scarcity of forage at the surface.

LITERATURE CITED

ANONYMOUS
1956. Albacore--What About Next Year? *Pacific Fisherman*, vol. 54, no. 11, pp. 32-33.

GRAHAM, J. J.
1957. Central North Pacific Albacore Surveys, May to November 1955. U. S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 212, 38 pp.

GRAHAM, J. J. and MANN, H. J.
1959. Construction and Catch Selectivity of Albacore Gill Nets Used in the Central North Pacific. *Commercial Fisheries Review*, vol. 21, no. 8 (August), pp. 1-6. (Also Sep. No. 556.)

McGARY, J. W. and GRAHAM, J. J.
1960. Biological and Oceanographic Observations in the Central North Pacific, July-September 1958. U. S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 358, 107 pp.

McGARY, J. W.; JONES, E. C.; and GRAHAM, J. J.
1958. Enrichment in the Transition Zone Between the Subarctic and Central Water Masses of the Central North Pacific. *Proceedings of the Ninth Pacific Science Congress, 1957*, vol. 16, pp. 82-89.

POWELL, D. E. and PETERSON, A. E.
1957. Experimental Fishing to Determine Distribution of Salmon in the North Pacific Ocean, 1955. U. S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 205, 30 pp.

TESTER, A. L.
1956. The Where and Why of Albacore. *Pacific Fisherman*, vol. 54, no. 4, pp. 21, 23-24.

U. S. FISH AND WILDLIFE SERVICE
1957-59. Ten-Day Sea Surface Temperature Charts of the Eastern North Pacific, 7 pp., Bureau of Commercial Fisheries, Honolulu Biological Laboratory (mimeographed).

---

[3] This trend was determined by inspection. Also, the data were examined using the Chi-square. A hypothesis was set up that the fish were distributed in the net in a 1:1:1 ratio in the top, middle, and bottom. The sums of the Chi-squares of the first five stations showed a statistically significant deviation from this expected ratio ($X^2 = 102.05$, degrees of freedom 9). The interaction between sets was also statistically significant ($X^2 = 90.04$, degrees of freedom 7), and it is thought that this heterogeneity lends credence to the suggested trend.

* * *

DISPLAY COPY

Oceanographic Observations made during a Cooperative Survey of Albacore (*Thunnus Germo*) off the North American West Coast in 1959

SPECIAL SCIENTIFIC REPORT—FISHERIES No. 386

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

United States Department of the Interior, Stewart L. Udall, Secretary
Fish and Wildlife Service, Clarence F. Pautzke, Commissioner
Bureau of Commercial Fisheries, Donald L. McKernan, Director

OCEANOGRAPHIC OBSERVATIONS MADE DURING A COOPERATIVE SURVEY OF ALBACORE (THUNNUS GERMO) OFF THE NORTH AMERICAN WEST COAST IN 1959

By

Joseph J. Graham
Fishery Research Biologist
Bureau of Commercial Fisheries
Biological Laboratory, Honolulu, Hawaii

and

William L. Craig
Marine Biologist
Marine Resources Operations
California Department of Fish and Game

March 3, 1849

United States Fish and Wildlife Service
Special Scientific Report: Fisheries No. 386

Washington, D. C.
August 1961

ABSTRACT

This report lists the physical, chemical, and biological data collected by scientists aboard the Hugh M. Smith of the Bureau of Commercial Fisheries and N. B. Scofield of the California Department of Fish and Game during the spring and early summer of 1959 off the coast of California and Baja California, Mexico. The purpose of the cruises was to locate the route of the spring migration of albacore into west coast waters and the subsequent early concentrations of these fish.

CONTENTS

Page

Introduction 1

Itinerary 1

Meteorological observations 1

Physical and chemical observations 2

    Temperatures 2

    Light penetration and water color 3

    Salinity and inorganic phosphate 3

Biological observations 7

    Isotopic Carbon (C_{14}) primary productivity samples 7

    Zooplankton collections 7

    Night-light observations 7

    Occurrence of fish, birds, and aquatic mammals 7

Miscellaneous observations 7

Acknowledgments 7

Literature cited 8

ILLUSTRATIONS

Figure Page

1. Track of Hugh M. Smith cruise 52 2

2. Track of N. B. Scofield cruise 59S4 3

3. Surface temperature (upper panel) and temperature-depth profiles (lower panel) for successive legs of Hugh M. Smith cruise 52. For general location of legs, see the track chart. Positions of designated points of the legs are: A -- 39° N., 135° W.; B -- 31° N., 125° W.; C -- 27° N., 122° W.; D -- 27° N., 110°30' W.; E -- 31° N., 125° W.; F -- 29°30' N., 118° W.; and G -- 27° N., 122° W. . . . . 4 and 5

4. Surface temperature (upper panel) and temperature-depth profiles (lower panel) for successive legs of N. B. Scofield cruise 59S4. For general location of legs, see the track chart. Positions of designated points of the legs are: A -- 36°30' N., 126°30' W.; B -- 32° N., 127°30' W.; C -- 38° N., 128° W.; D -- 32° N., 124° W.; E -- 35°30' N., 124°30' W.; and F -- 32° N., 123° W. 6

TABLES

Table Page

1. Summary of weather observations (USWB 1210-F), Hugh M. Smith cruise 52 9

2. Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 52 16

3. Summary of observations at bathythermograph lowerings, N. B. Scofield cruise 59S4 23

4. Oceanographic observations, Hugh M. Smith cruise 52 25

5. Oceanographic observations, N. B. Scofield cruise 59S4 28

6. Sightings of tuna schools, birds, and aquatic mammals, Hugh M. Smith cruise 52 30

7. Sightings of birds and aquatic mammals, N. B. Scofield cruise 59S4 31

OCEANOGRAPHIC OBSERVATIONS MADE DURING A COOPERATIVE SURVEY OF ALBACORE (THUNNUS GERMO) OFF THE NORTH AMERICAN WEST COAST IN 1959

By

Joseph J. Graham [1]
Fishery Research Biologist
Bureau of Commercial Fisheries
Biological Laboratory, Honolulu, Hawaii

and

William L. Craig
Marine Biologist
Marine Resources Operations
California Department of Fish and Game

The North American west coast fishery for albacore, Thunnus germo (Lacépède), usually extends from central Baja California, Mexico, to central California, but at times it has extended as far north as Queen Charlotte Island, Canada. The fishery begins during the spring and early summer off the coast of Baja California and southern California and reaches its peak there around August (Clemens, 1955). In the late summer and fall, the fishery shifts northward to central California and during some years develops off the coasts of Oregon and Washington (Powell et al., 1952). By winter, fishing is usually ended, although in some years a small winter fishery develops (Pacific Fisherman, 1956; California Department of Fish and Game, 1949).

The success of the summer fishery in any given year depends in part on how readily the commercial fishermen are able to locate concentrations of fish early in the season. With this in mind, a cooperative preseason survey of the west coast albacore fishing grounds was conducted in 1959 by the Bureau of Commercial Fisheries Biological Laboratory, Honolulu, Hawaii, and the California Department of Fish and Game. The intention was to locate the migration route of albacore into west coast waters and the areas of commercial concentration. This paper presents the meteorological, physical oceanographic, and biological data obtained and describes the methods used to collect them. Exploratory fishing results are the subject of another report (Craig and Graham, 1961).

ITINERARY

Cruise 52 of the Bureau of Commercial Fisheries vessel Hugh M. Smith and cruise 59S4 of the California Department of Fish and Game vessel N. B. Scofield covered areas off California and northern Baja California. The cruise tracks for the two vessels are shown in figures 1 and 2. The Hugh M. Smith (fig. 1) departed Honolulu on April 28 and proceeded to Point A (39° N., 135° W.). After reaching this point the cruise was interrupted on May 11 because of illness of a crewman, who was taken to San Francisco. On May 17 the cruise was resumed at the point where it had been interrupted. Because of the loss of time during the emergency run to San Francisco, a series of stations planned for the track between point D (27° N., 118° 30' W.) and San Diego was omitted. The Smith arrived at San Diego on May 27. The second portion of the survey (fig. 1, bottom panel) was begun on May 30 and was completed on June 19.

The Scofield departed Los Angeles harbor on June 1. After a brief stopover at Santa Barbara to obtain certain scientific equipment, the Scofield proceeded along the track shown in figure 2. The cruise was completed on June 25.

METEOROLOGICAL OBSERVATIONS

Marine weather observations were recorded daily by scientists aboard the Smith at 0000, 0600, 1200, and 1800 GCT and were transmitted daily to the U. S. Weather Bureau (table 1). Standard weather data were entered in the bathythermograph logs aboard both vessels (tables 2 and 3).

One storm, with maximum wind velocities of force 7, occurred within the 48-day cruise period of the Smith. During 10 percent of the

---

[1] Presently employed as Supervisory Fishery Biologist, Bureau of Commercial Fisheries Biological Laboratory, Galveston, Texas.

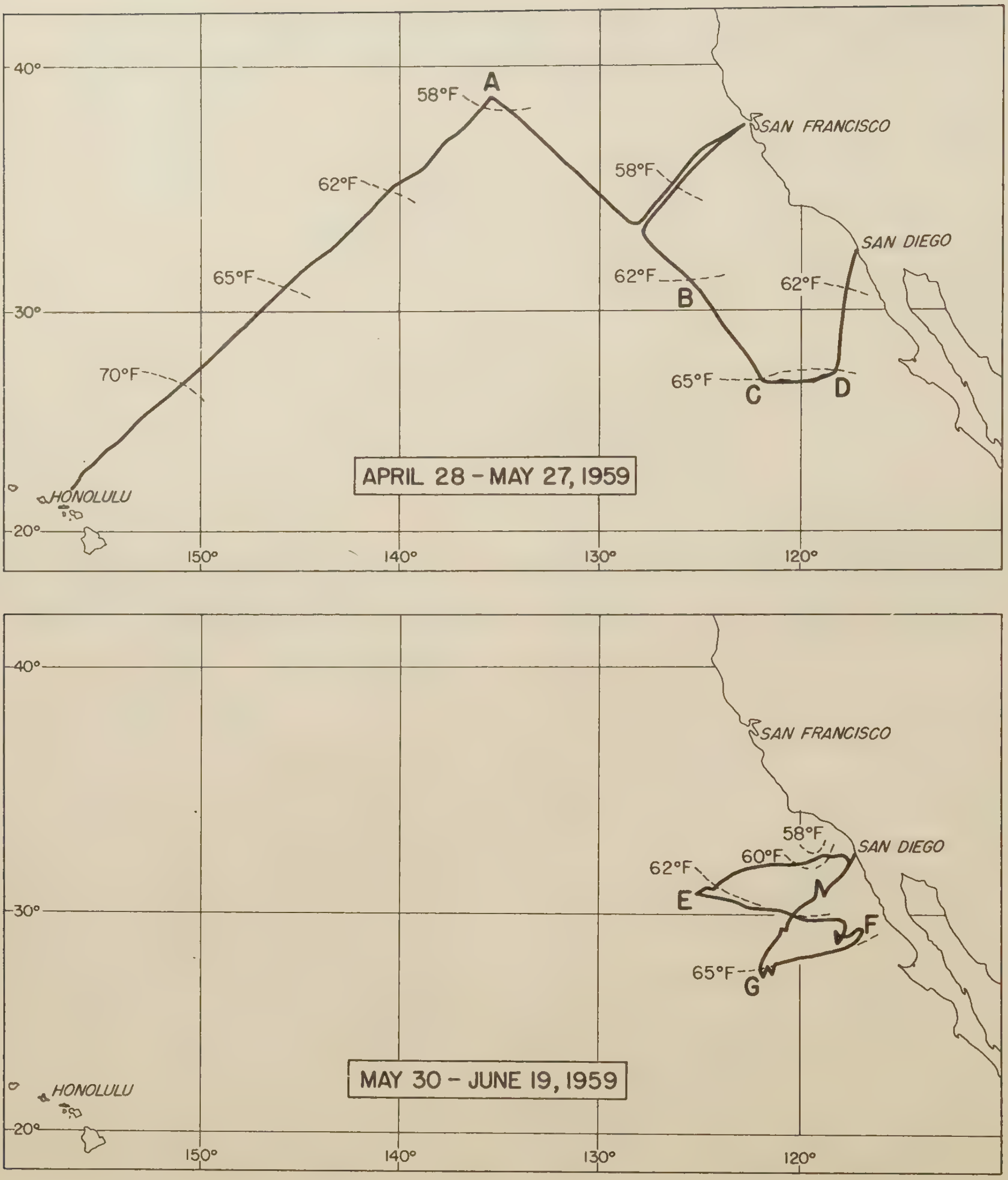

40°
30°
20°
150°
140°
130°
120°
SAN FRANCISCO
SAN DIEGO
HONOLULU
A
B
C
D
58°F
62°F
65°F
70°F
58°F
62°F
65°F
62°F
APRIL 28 - MAY 27, 1959
E
F
G
58°F
60°F
62°F
65°F
MAY 30 - JUNE 19, 1959

Figure 1.--Track of Hugh M. Smith cruise 52.

cruise period the winds exceeded force 5. In contrast, winds exceeding force 5 were recorded for 60 percent of the 21-day Scofield cruise; winds reached a maximum of force 8.

PHYSICAL AND CHEMICAL OBSERVATIONS

Temperatures

Bathythermograph casts were made to 900 feet at intervals of 30 to 60 miles along the cruise track of the Smith, and in addition a 900-foot and a 400- or 200-foot cast were made on all fishing stations. Casts to 400 feet were made from the Scofield approximately every 20 to 90 miles. The bathythermograph logs are reproduced in tables 2 and 3. The vertical temperature sections with accompanying bucket temperatures are shown in figures 3 and 4. The plots are based on BT slides processed at the Bureau

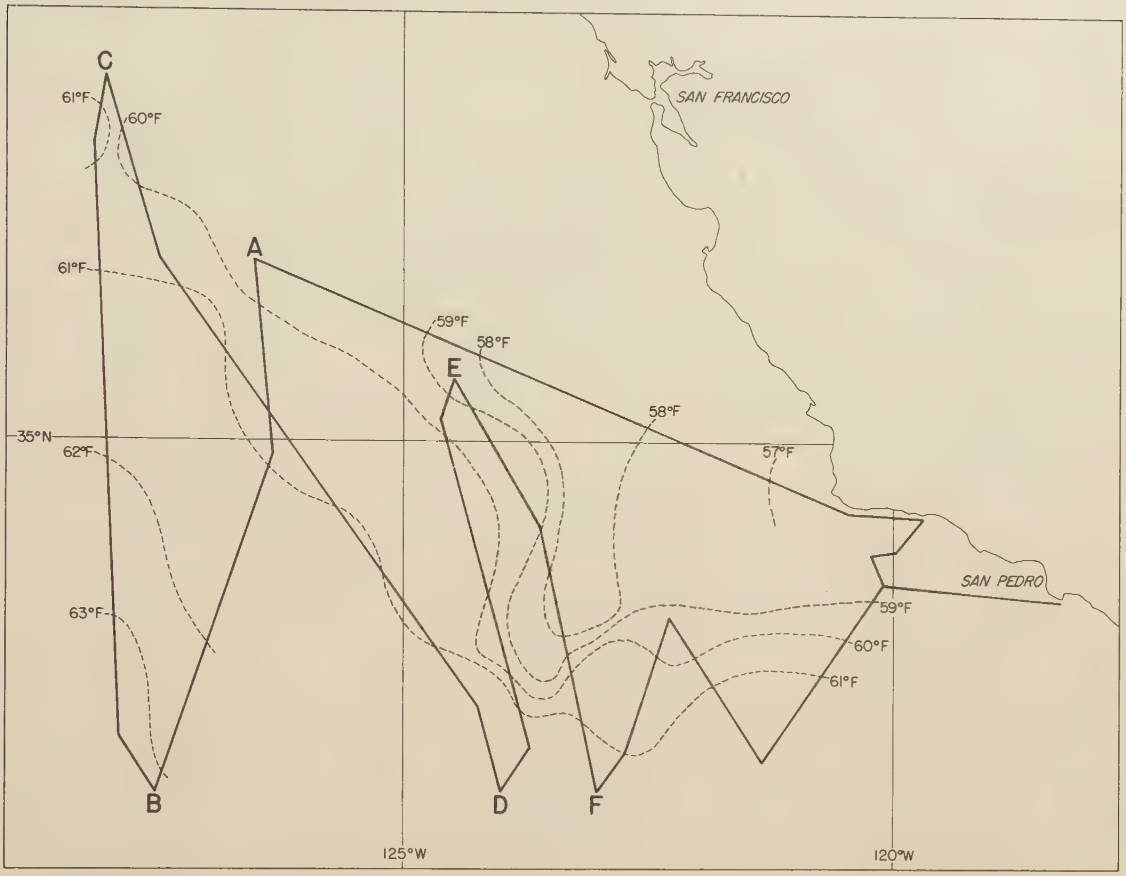


Figure 2.--Track of N. B. Scofield cruise 59S4.

of Commercial Fisheries Biological Laboratory, Honolulu, using methods described by Callaway (1957).

Continuous records of surface temperature were obtained along the cruise tracks of both vessels by means of recording thermographs.

Light Penetration and Water Color

Light penetration measurements were made from the Smith with a photometer and a Secchi disc, and water color was determined with a Forel color scale. Secchi disc measurements were also made from the Scofield. By means of the photometer, described by Callaway (1957), we determined the depths to which 50 percent, 10 percent, 5 percent, and 1 percent of sunlight were transmitted. Usually these measurements were made at noon (LCT). In a few instances observations were made from the Smith during the morning hours, but they were discontinued because it was found that there was insufficient sunlight to produce reliable readings. Light penetration and water color data and the average illumination on deck are given in tables 4 and 5.

Salinity and Inorganic Phosphate

Surface salinity samples were collected coincident with each BT cast from both the Smith and Scofield. Samples were also obtained from the Smith fishing stations. Surface water samples, frozen for subsequent analysis of their inorganic phosphate content, were obtained from the Scofield with each BT cast. On the Smith, samples for phosphate analysis were collected at BT casts at approximately 90-mile intervals between Oahu and point B (32° N., 127° 30' W.), and at 30-mile intervals east of point B; they were also collected at every fishing station. All salinity and inorganic phosphate samples were analyzed at the Bureau of Commercial Fisheries Biological Laboratory, Honolulu. Salinity samples were processed using a modification of the Mohr method (Van Landingham,1957) and inorganic phosphate by a modification of the molybdenum method using the Beckman Photometer Model B (King et al., 1957). The data taken

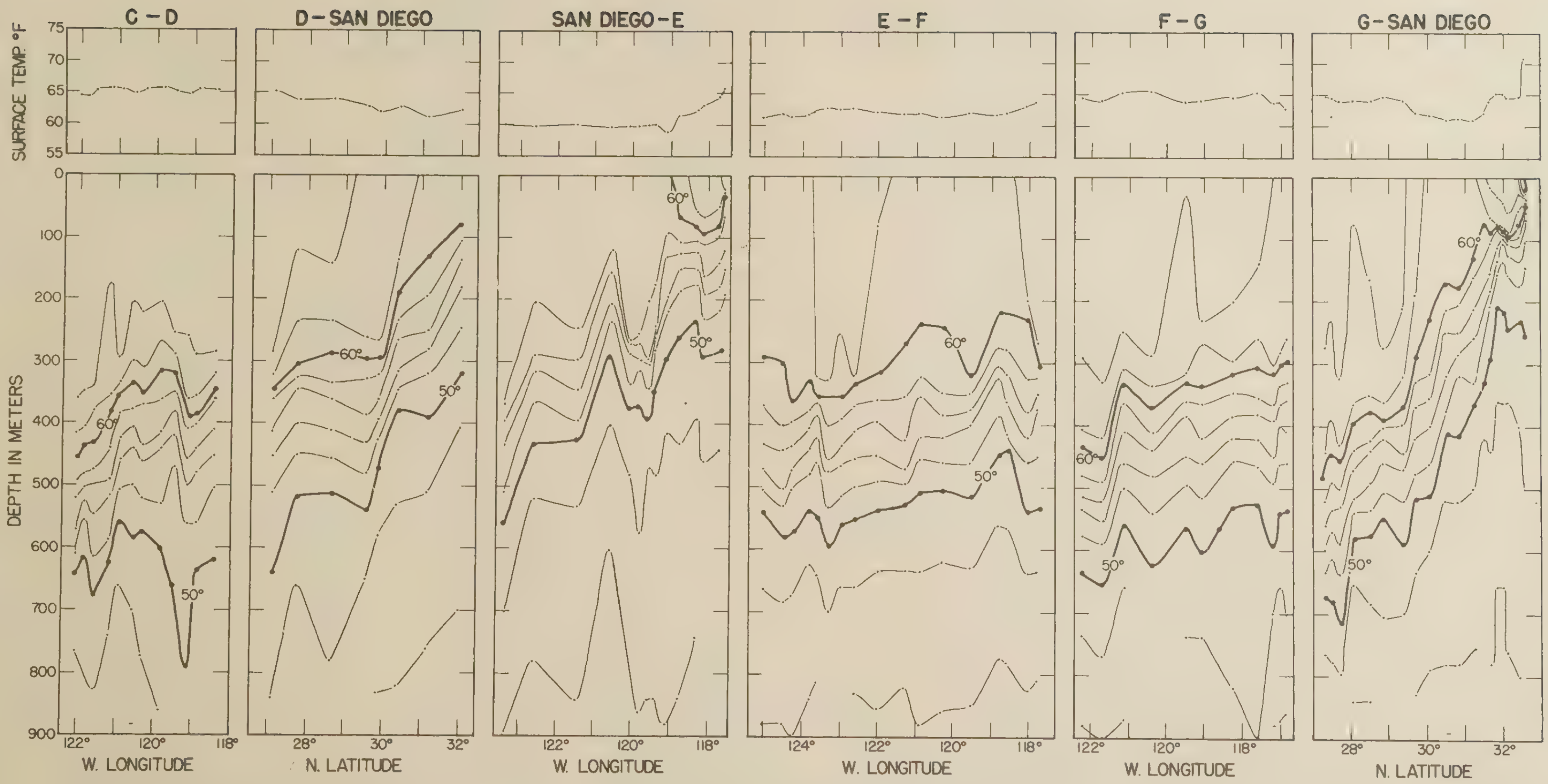


Figure 3.--Surface temperature (upper panel) and temperature-depth profiles (lower panel) for successive legs of Hugh M. Smith cruise 52. For general location of legs, see the track chart. Positions of designated points of the legs are: A -- 39° N., 135° W.; B -- 31° N., 125° W.; C -- 27° N., 122° W.; D -- 27° N., 110° 30' W.; E -- 31° N., 125° W.; F -- 29° 30' N., 118° W.; and G -- 27° N., 122° W.

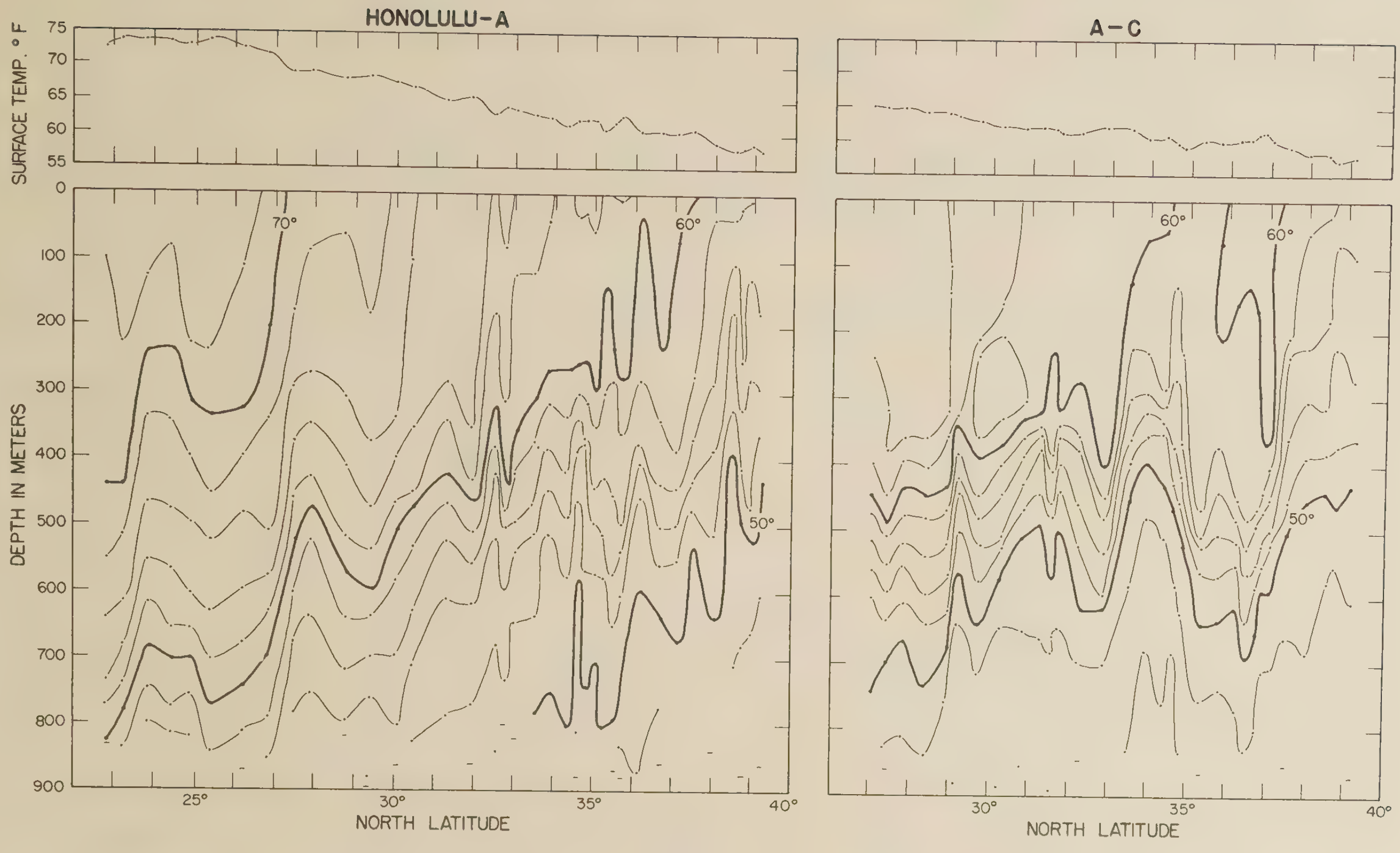


Figure 3.--Surface temperature (upper panel) and temperature-depth profiles (lower panel) for successive legs of Hugh M. Smith cruise 52. For general location of legs, see the track chart. Positions of designated points of the legs are: A -- 39° N., 135° W.; B -- 31° N., 125° W.; C -- 27° N., 122° W.; D -- 27° N., 110° 30' W.; E -- 31° N., 125° W.; F -- 29° 30' N., 118° W.; and G -- 27° N., 122° W. (con.)

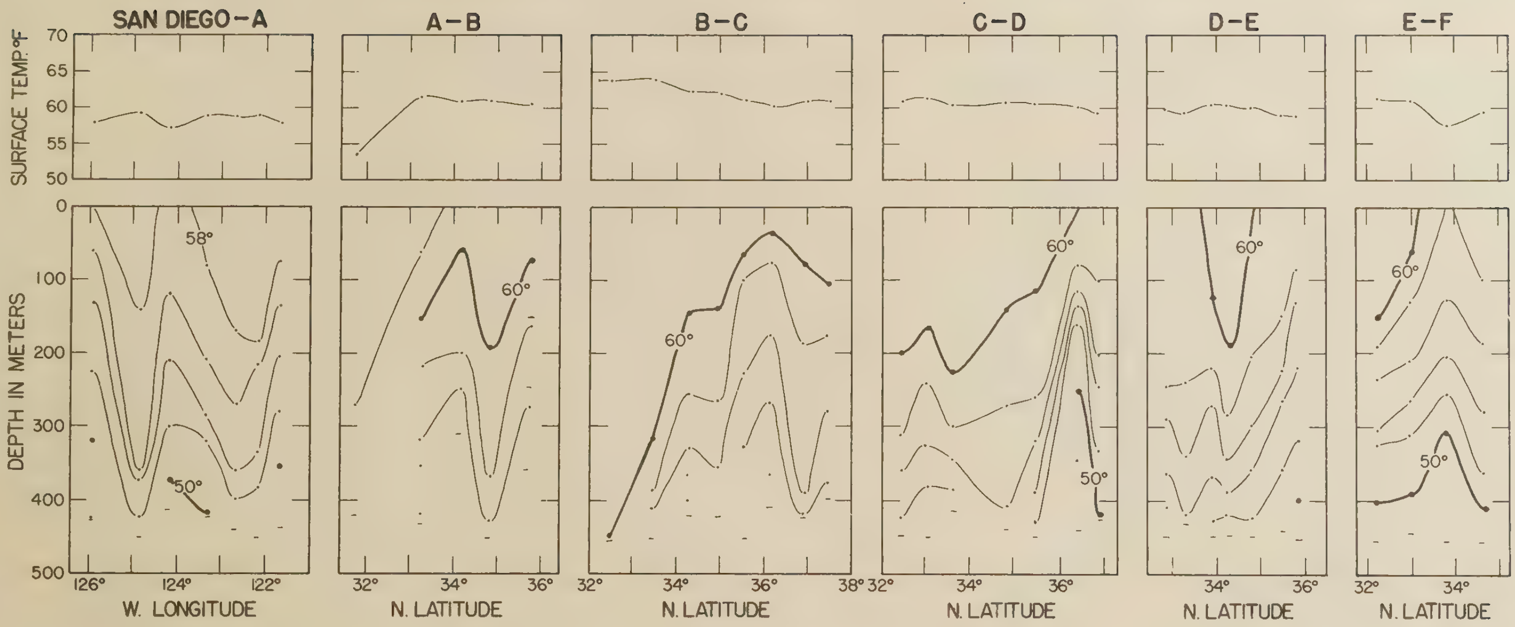


Figure 4.--Surface temperature (upper panel) and temperature-depth profiles (lower panel) for successive legs of N. B. Scofield cruise 59S4. For general location of legs, see the track chart. Positions of designated points of the legs are: A -- 36° 30' N., 126° 30' W.; B -- 32° N., 127° 30' W.; C -- 38° N., 128° W.; D -- 32° N., 124° W.; E -- 35° 30' N., 124° 30' W.; and F -- 32° N., 123° W.

coincidentally with stations are given in tables 4 and 5; those associated with BT lowerings while under way are listed in tables 2 and 3.

BIOLOGICAL OBSERVATIONS

Isotopic Carbon (C_{14}) Primary Productivity Samples

Surface water samples for the analysis of C_{14} uptake by phytoplankton were collected by scientists of both vessels with a clean plastic bucket. They were then transferred to one "dark" and two "light" bottles, inoculated with radioactive sodium carbonate solution and incubated in an illuminated water bath. The details followed in these procedures were those described by King et al. (1957). Collections were made around noon from both vessels. In a few instances some were made at other times when abrupt changes in temperature, light penetration, or other environmental entities occurred. The carbon fixation measurements and calculations of the rate of carbon fixation (tables 4 and 5) were made using techniques developed by Steemann Nielsen (1952) and modified by Doty and Oguri (1958).

Zooplankton Collections

Night surface tows were made from the Smith for a period of 20 minutes with a 1-meter plankton net. Similar tows were made at dusk from the Scofield. The net towed from the Smith was constructed of Nitex and had a mesh aperture of 0.656 mm. The amount of water strained was metered with an Atlas flow meter which had been calibrated at the time of the Smith's departure from Honolulu. The net used on the Scofield was on loan from the Bureau of Commercial Fisheries Biological Laboratory, La Jolla, and was described as a 1-meter net having an anterior portion of 30XXX grit gauze, Dufour bolting cloth (silk) and a posterior portion and cod end of 56XXX grit gauze. Aperture size (mode) of these two portions was 0.0278 inches and 0.0125 inches, respectively. The Japanese flow meter used was calibrated after the cruise. All plankton samples were preserved in 10-percent formalin buffered with borax and returned to the Bureau of Commercial Fisheries Biological Laboratory, Honolulu. The wet drained weight was determined for each sample and entered in tables 4 and 5 in terms of grams per 1,000 cubic meters of water strained.

Night-light Observations

Night-light observations were made from both the Smith and the Scofield. Observations from the Smith were for a period of 1 hour using as illumination the overside lights and the stern deck light. The Scofield was equipped with a 1,500-watt bulb with a reflector suspended 3 to 4 feet above the water. A single station was occupied by the Scofield for a period of 2 1/2 hours; other stations were planned but omitted because of the necessity to maintain headway against high seas. Data obtained by the two vessels are shown in tables 4 and 5.

Occurrence of Fish, Birds, and Aquatic Mammals

Wheel watches of the Smith maintained logs of fish, birds, and aquatic mammals sighted during daylight hours. Similar observations were made from the Scofield and recorded in the scientists' log. These observations are tabulated in tables 6 and 7.

MISCELLANEOUS OBSERVATIONS

Miscellaneous observations were made by scientists aboard the Smith as follows: (1) A collection of shark intervertebral tissue was made for Dr. Karl Meyer of Columbia University, New York. (2) Blood serum was extracted for racial studies from two bigeye tuna, Parathunnus sibi (Temminck and Schlegel), and one skipjack tuna, Katsuwonus pelamis (Linnaeus), for the Bureau of Commercial Fisheries Biological Laboratory, Seattle, Washington. (3) A small net was placed in the rigging of the ship, and the removable cod end was changed at noon for 19 days in an effort to capture airborne insects for the Bishop Museum of Honolulu, Hawaii. (4) Fifteen times during the cruise of the Smith C_{14} samples were incubated by towing them astern in a manner requested by Dr. M. S. Doty of the University of Hawaii at Honolulu, Hawaii.

ACKNOWLEDGMENTS

Field Party Personnel:

Hugh M. Smith

Robert E. K. D. Lee - Master
Joseph J. Graham - Field Party Chief
Murice O. Rinkel - Oceanographer
Richard N. Uchida - Fishery Research Biologist

N. B. Scofield

Richard B. Mitchell - Master
William L. Craig - Field Party Chief
Donald A. Carvalho - Assistant

We wish to thank the captains and crews of the Hugh M. Smith and N. B. Scofield for their cooperation during the survey. The crew of the Scofield collected data under particularly trying weather conditions. We also wish to acknowledge the assistance extended to the field party of the Smith during her stay in the port of San Diego by staff members of the Bureau of Commercial Fisheries Biological Laboratories at San Diego and La Jolla, California.

LITERATURE CITED

CALIFORNIA DEPARTMENT OF FISH AND GAME
1949. The commercial fish catch of California for the year 1947 with a historical review. 1916-1947. California Department of Fish and Game, Fish Bulletin 74, 267 pp.

CALLAWAY, RICHARD J.
1957. Oceanographic and meteorological observations in the northeast and central North Pacific, July - December 1956. U. S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 230, 49 pp.

CLEMENS, H. B.
1955. Catch localities for Pacific albacore (Thunnus germo) landed in California, 1951 through 1953. California Department of Fish and Game, Fish Bulletin 100, 28 pp.

CRAIG, WILLIAM L., and JOSEPH J. GRAHAM
1961. Report on a co-operative, preseason survey of the fishing grounds for albacore (Thunnus germo) in the eastern North Pacific, 1959. California Fish and Game, vol. 47, No. 1, p. 73-85.

DOTY, M. S., and M. OGURI
1958. Selected features of the isotopic carbon primary productivity technique. Rapports et Proces-Verbaux du Conseil Permanent International pour l' Exploration de la Mer., vol. 144, p. 47-55.

KING, J. E., T. S. AUSTIN, and M. S. DOTY
1957. Preliminary report on expedition EASTROPIC. U.S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 201, 155 pp.

PACIFIC FISHERMAN
1956. Albacore--What about next year ? Pacific Fisherman, vol. 54, No. 11, p. 32-33.

POWELL, D. E., D. L. ALVERSON, and R. LIVINGSTONE, Jr.
1952. North Pacific albacore tuna exploration--1950. U. S. Fish and Wildlife Service, Fishery Leaflet No. 402, 56 pp.

SNODGRASS, J. M., D. E. CARRITT, and W. S. WOOSTER
1954. Automatic servo-operated filter photometer. Analytical Chemistry, vol. 26, No. 1, p. 249-250.

STEEMANN NIELSEN, E.
1952. The use of radioactive-carbon (C_{14}) for measuring organic production in the sea. Journal du Conseil Permanent International pour l' Exploration de la Mer, vol. 18, No. 2, p. 117-140.

VAN LANDINGHAM, J. W.
1957. A modification of the Knudsen method for salinity determination. Journal du Conseil Permanent International pour l' Exploration de la Mer, vol. 22, No. 2, p. 174-179.

Table 1.--Summary of weather observations (USWB 1210-F), Hugh M. Smith cruise 52

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. cor. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
4/29	22.3°	156.6°	1200	99	09	18	02	2	1020.7	7	0.6	73.4	68.0	73.7	6	7	1	5	4	0	08	2	3
4/29	22.8°	156.0°	1800	98	11	19	95	8	1022.0	2	1.4	71.2	68.7	72.2	6	6	7	5	0	0	11	2	3
4/30	23.3°	155.3°	0000	98	12	17	01	1	1019.6	0	1.8	76.8	69.4	73.1	2	2	2	5	0	0	10	4	2
4/30	23.8°	154.7°	0600	98	08	15	02	0	1021.0	2	2.0	73.0	68.8	73.5	1	1	9	5	0	0	08	4	3
4/30	24.4°	153.9°	1200	98	11	16	02	0	1021.0	8	1.0	72.2	67.5	73.1	1	1	1	5	0	0	10	3	2
4/30	25.0°	153.2°	1800	98	10	16	25	8	1021.7	3	1.0	73.7	66.4	72.7	2	2	9	5	0	0	10	3	2
5/1	25.6°	152.5°	0000	98	11	14	02	0	1020.7	7	1.2	73.7	66.8	73.2	1	1	2	5	0	0	10	2	2
5/1	26.2°	151.8°	0600	98	10	14	02	0	1021.7	3	1.1	72.4	65.2	72.2	1	1	9	5	0	0	06	2	2
5/1	26.8°	151.0°	1200	98	11	09	02	0	1021.5	7	0.6	71.5	67.8	71.2	1	1	1	5	0	0	10	2	2
5/1	27.4°	150.3°	1800	98	11	17	15	8	1022.4	2	1.0	70.4	65.0	68.8	6	6	8	5	0	0	10	4	3
5/2	28.0°	149.5°	0000	98	09	12	01	1	1022.4	8	0.6	70.1	63.2	68.8	2	1	8	5	0	5	10	4	3
5/2	28.7°	148.8°	0600	98	09	15	02	0	1024.4	3	2.0	69.0	61.8	68.0	2	2	1	5	0	0	10	4	2
5/2	29.3°	148.0°	1200	98	11	14	00	X	1024.4	7	1.0	66.9	59.7	67.7	X	X	X	X	X	X	10	3	2
5/2	29.9°	147.2°	1800	98	12	14	03	1	1027.1	2	1.4	66.7	59.3	67.1	7	7	5	5	0	0	12	2	2
5/3	30.5°	146.5°	0000	98	12	11	01	1	1026.4	8	0.7	66.0	57.6	65.1	3	1	1	5	0	4	02	4	2
5/3	31.1°	145.7°	0600	98	10	13	02	0	1027.8	3	1.2	64.7	57.8	64.9	4	1	1	5	0	5	02	4	1
5/3	31.8°	144.8°	1200	98	11	12	03	1	1027.4	8	0.9	63.8	57.4	65.2	5	2	1	5	0	6	06	2	1
5/3	32.4°	144.0°	1800	98	14	10	03	2	1029.1	3	1.7	63.4	55.6	63.4	7	2	1	5	0	6	10	2	1
5/4	32.8°	143.4°	0000	98	15	11	01	2	1029.1	7	1.4	64.8	57.5	63.8	4	1	1	5	0	5	05	4	1
5/4	33.3°	142.8°	0600	98	16	10	02	2	1029.8	3	0.8	63.0	57.2	62.7	4	2	1	5	0	5	04	4	1
5/4	33.7°	142.2°	1200	98	16	12	01	1	1028.1	8	1.5	61.8	56.3	61.7	1	1	5	5	0	1	15	2	0
5/4	34.1°	141.6°	1800	98	18	11	03	0	1029.1	3	1.2	62.6	56.8	61.4	3	1	4	5	0	4	02	3	1
5/5	34.6°	141.0°	0000	98	23	10	02	1	1029.1	8	0.2	64.2	58.0	62.3	7	1	5	5	0	7	22	2	1
5/5	34.8°	140.7°	0600	98	21	09	03	2	1029.8	3	0.9	64.3	58.0	62.0	8	2	5	5	0	7	22	2	1
5/5	34.7°	140.9°	1200	98	22	10	01	1	1029.1	6	0.8	62.6	58.2	61.8	0	0	0	9	0	0	25	2	1
5/5	35.0°	140.5°	1800	98	25	07	03	0	1030.8	3	1.4	62.7	59.5	61.0	1	1	4	5	0	5	29	5	0
5/6	35.5°	139.9°	0000	98	24	06	03	0	1030.8	8	0.2	65.4	60.4	62.9	2	1	2	5	1	5	29	4	1
5/6	35.9°	139.2°	0600	98	24	06	03	0	1031.8	3	0.8	61.3	59.8	60.8	3	1	2	5	0	5	29	4	1
5/6	36.4°	138.6°	1200	98	23	03	01	0	1031.2	6	0.6	60.4	59.6	60.6	1	1	X	X	X	X	XX	X	X
5/6	36.8°	138.0°	1800	98	26	03	03	0	1032.2	1	0.6	62.7	59.4	61.3	2	1	2	5	1	5	30	4	2

X - Not observed

Table 1.--Summary of weather observations (USWB 1210-F), Hugh M. Smith cruise 52 - con.

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. cor. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
5/7	36.8°	138.1°	2300	98	25	07	03	0	1031.5	8	0.8	65.3	59.3	61.9	3	2	2	5	0	2	28	4	2
5/7	37.2°	137.5°	0600	98	23	06	02	0	1029.8	3	0.2	61.9	58.8	61.0	3	2	2	5	3	5	29	5	3
5/7	37.8°	136.8°	1200	98	23	09	02	0	1027.1	6	1.7	62.6	58.9	58.8	3	X	X	X	X	X	XX	X	X
5/7	38.3°	136.2°	1800	98	20	07	03	1	1026.8	7	0.2	62.4	59.8	58.1	7	6	3	5	7	5	28	5	3
5/8	38.7°	135.5°	0000	98	23	06	01	2	1025.7	7	1.0	64.7	60.2	58.6	6	1	2	6	7	6	28	5	3
5/8	38.9°	135.2°	0600	98	21	07	01	1	1026.8	3	0.7	59.9	58.0	57.7	2	2	X	X	X	X	28	5	2
5/8	38.8°	135.1°	1200	98	35	13	03	1	1027.8	2	0.2	58.8	56.8	57.4	8	8	X	X	X	X	29	2	1
5/8	38.7°	134.9°	1800	98	35	14	15	5	1032.2	2	2.4	57.8	53.7	57.0	7	7	7	4	0	0	35	2	1
5/9	38.3°	134.4°	0000	98	35	14	02	2	1032.5	0	0.0	57.6	52.7	58.0	7	7	5	4	0	0	35	2	2
5/9	37.8°	133.7°	0600	98	01	15	01	2	1033.2	3	0.7	56.6	51.2	58.25	6	2	5	4	0	6	33	2	3
5/9	37.3°	133.2°	1200	98	01	08	01	1	1031.2	7	1.0	55.8	50.6	59.4	3	2	5	4	0	5	XX	X	X
5/9	36.8°	132.6°	1800	98	36	14	03	2	1031.5	0	0.2	59.0	53.8	60.6	7	7	5	4	0	0	35	5	3
5/10	36.5°	132.2°	0000	98	36	12	02	2	1029.1	8	2.0	59.8	54.3	61.0	8	8	6	4	X	X	32	4	4
5/10	36.7°	132.4°	0600	97	36	14	50	5	1027.1	8	0.3	58.9	56.6	61.1	8	8	7	4	X	X	32	3	3
5/10	36.7°	132.4°	1200	97	01	09	50	5	1024.4	6	1.4	58.7	56.2	67.2	8	8	7	4	X	X	36	2	2
5/10	36.5°	132.2°	1800	98	06	09	02	5	1023.7	7	0.3	57.9	55.0	60.9	7	7	7	4	0	0	36	4	2
5/11	36.1°	131.5°	0000	98	05	12	02	2	1020.3	7	2.0	59.4	54.2	60.25	7	7	5	4	0	0	04	2	2
5/11	35.6°	131.0°	0600	98	07	12	01	1	1018.0	6	0.5	57.3	54.5	59.8	3	3	X	X	X	X	05	2	2
5/11	35.2°	130.4°	1200	98	04	12	01	0	1015.6	7	1.0	57.8	55.0	60.0	2	1	1	5	0	5	05	2	2
5/11	34.7°	129.7°	1800	98	04	14	02	0	1015.2	4	0.0	60.8	55.8	59.1	2	1	1	5	0	5	04	2	3
5/12	34.2°	129.1°	0000	98	04	14	02	0	1012.2	7	1.6	59.6	56.6	60.9	2	2	1	5	0	0	05	2	3
5/12	33.8°	128.6°	0600	98	07	08	03	0	1011.5	3	0.2	58.6	55.7	60.2	3	X	X	X	X	X	03	2	2
5/12	33.7°	127.9°	1200	98	32	06	03	1	1010.5	8	0.4	59.5	55.0	60.1	6	X	X	X	X	X	04	2	2
5/12	34.4°	127.1°	1800	98	05	10	03	2	1012.2	2	1.4	60.9	55.4	58.6	8	8	5	5	X	X	36	3	4
5/13	35.1°	126.3°	0000	98	20	12	01	2	1012.5	2	0.5	60.7	56.0	58.2	7	6	5	5	0	6	35	3	2
5/13	35.8°	125.5°	0600	98	18	12	03	2	1015.2	2	1.7	60.0	57.4	57.8	8	X	X	X	X	X	35	3	1
5/13	36.5°	124.4°	1200	98	18	09	01	1	1016.6	1	1.0	58.0	56.4	56.0	3	X	X	X	X	X	36	2	1
5/13	37.2°	123.4°	1800	98	14	11	03	1	1017.3	3	1.4	58.4	56.2	54.2	7	6	5	5	3	0	35	3	2
5/15	37.4°	123.0°	1800	98	32	28	02	0	1021.0	1	1.0	55.6	51.2	54.1	0	0	0	9	0	0	30	2	6
5/16	37.4°	123.6°	0000	98	33	28	02	0	1020.3	5	0.0	56.6	51.0	54.5	0	0	0	9	0	0	32	2	8

Table 1.--Summary of weather observations (USWB 1210-F), Hugh M. Smith cruise 52 - con.

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. cor. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
5/16	37.3°	124.2°	0600	98	34	22	03	0	1021.0	3	0.7	55.6	51.9	53.0	3	0	0	9	0	5	32	3	6
5/16	36.6°	125.0°	1200	98	34	20	00	0	1020.7	7	0.2	56.3	52.7	58.2	1	1	8	4	0	0	32	3	4
5/16	36.0°	125.8°	1800	98	32	13	03	1	1021.7	3	1.2	57.8	54.1	57.1	6	1	1	5	0	6	32	3	3
5/17	35.2°	126.4°	0000	98	31	15	02	2	1021.7	6	0.5	61.6	56.2	59.6	6	2	2	5	0	6	32	3	2
5/17	34.4°	127.1°	0600	98	31	14	03	2	1021.7	3	0.8	61.3	56.9	59.2	7	0	0	9	0	7	31	3	2
5/17	33.7°	127.9°	1200	98	31	16	01	1	1021.0	6	0.3	61.3	57.8	61.0	0	0	0	9	0	0	31	3	2
5/17	33.3°	128.0°	1800	98	35	14	25	1	1023.4	2	2.0	62.0	59.8	61.0	7	7	9	4	0	0	31	3	2
5/18	33.3°	127.9°	0000	98	36	09	02	2	1023.7	7	0.3	65.8	55.7	61.9	6	2	0	5	5	6	31	4	3
5/18	32.8°	127.2°	0600	98	36	07	01	1	1024.4	3	0.7	61.6	56.8	61.5	1	1	1	5	0	0	36	4	3
5/18	32.1°	126.4°	1200	98	36	10	03	1	1022.4	6	1.0	59.9	55.1	60.9	7	X	X	X	X	X	36	4	2
5/18	31.6°	125.7°	1800	98	01	16	01	1	1024.4	1	0.8	62.0	56.0	61.2	2	2	1	5	0	0	34	4	4
5/19	31.2°	125.2°	0000	98	36	21	02	1	1022.4	7	1.5	61.3	56.2	62.0	6	3	3	5	6	0	35	3	5
5/19	30.7°	124.8°	0600	98	01	21	02	2	1022.4	2	0.9	60.6	53.7	61.8	6	6	8	5	0	0	02	3	4
5/19	30.2°	124.3°	1200	98	01	23	02	2	1020.3	7	1.0	60.2	54.9	62.0	5	5	8	5	0	0	02	3	5
5/19	29.6°	124.1°	1800	98	36	26	01	2	1021.7	2	0.7	63.8	58.0	62.9	4	5	3	5	0	0	02	4	8
5/20	29.1°	123.7°	0000	98	02	24	01	0	1019.0	8	1.2	63.6	58.7	63.5	4	3	2	5	0	0	36	4	7
5/20	28.9°	123.5°	0600	98	36	22	03	1	1019.3	3	0.3	62.9	57.8	64.0	7	7	8	5	0	0	36	4	6
5/20	29.4°	123.7°	1200	98	01	22	30	1	1018.6	7	0.6	61.6	58.7	63.2	3	2	7	5	0	6	36	4	6
5/20	29.6°	123.9°	1800	98	02	20	25	8	1020.3	1	1.0	63.3	58.7	63.4	7	7	3	4	0	0	34	3	6
5/21	29.9°	124.1°	0000	98	36	22	02	8	1018.3	7	1.7	63.3	57.0	62.8	6	6	3	5	0	0	34	3	6
5/21	29.8°	124.0°	0600	98	36	21	01	1	1019.0	2	1.0	61.0	56.9	62.8	3	3	1	5	0	0	34	3	6
5/21	29.3°	123.7°	1200	98	34	18	03	1	1017.3	7	1.0	60.9	55.3	63.1	7	7	8	5	0	0	34	3	5
5/21	28.9°	123.4°	1800	98	01	14	02	2	1018.6	2	0.8	61.8	54.8	63.9	7	7	5	5	0	0	35	4	6
5/22	28.9°	123.4°	0000	98	33	14	02	2	1016.3	6	1.8	62.4	55.8	64.1	7	7	5	5	0	0	35	4	6
5/22	28.3°	123.0°	0600	98	35	09	02	2	1016.6	2	0.7	61.9	56.2	63.7	7	7	5	5	0	0	34	3	3
5/22	27.8°	122.5°	1200	98	35	06	02	2	1015.2	6	0.5	61.8	56.3	64.7	8	8	5	5	X	X	35	3	2
5/22	27.3°	122.1°	1800	98	28	06	02	2	1015.6	1	0.7	62.8	56.7	64.8	8	8	5	5	X	X	32	3	2
5/23	27.4°	122.1°	0000	98	35	10	02	2	1014.6	7	0.4	63.9	57.2	65.2	8	8	8	5	X	X	34	3	2
5/23	27.1°	122.0°	0600	98	36	09	02	2	1015.6	1	1.3	63.2	57.7	65.1	8	8	8	5	X	X	34	3	2
5/23	27.1°	122.0°	1200	98	32	11	80	2	1015.2	6	0.8	60.2	57.6	65.0	8	8	7	5	X	X	33	2	1

Table 1.--Summary of weather observations (USWB 1210-F), Hugh M. Smith cruise 52 - con.

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. cor. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
5/23	26.9°	121.9°	1800	98	36	08	15	8	1017.6	2	1.6	61.8	58.3	65.0	3	3	9	5	4	0	36	2	1
5/24	26.9°	121.2°	0000	98	03	05	15	8	1016.9	7	0.7	62.3	57.7	66.1	3	3	9	5	7	0	01	3	1
5/24	27.0°	120.9°	0600	98	36	03	15	8	1018.3	2	1.1	63.4	56.0	65.7	7	7	9	5	X	X	36	2	1
5/24	27.0°	120.9°	1200	98	33	11	02	2	1017.6	6	0.4	63.3	54.5	65.2	7	7	5	5	0	0	33	3	2
5/24	27.0°	120.6°	1800	98	36	07	02	2	1019.6	2	0.8	64.8	55.2	65.3	7	7	8	5	0	0	35	4	1
5/25	27.0°	119.8°	0000	98	35	07	02	2	1019.0	8	0.9	64.7	55.3	65.9	6	6	8	5	0	0	35	3	1
5/25	27.0°	119.5°	0600	98	35	11	02	2	1019.6	3	1.0	64.3	56.2	65.2	5	5	8	5	0	0	35	3	1
5/25	27.0°	119.5°	1200	98	34	17	02	2	1018.6	8	0.4	63.7	58.6	65.2	6	6	8	5	0	0	35	2	1
5/25	27.0°	119.1°	1800	98	02	13	02	2	1021.0	2	0.4	64.8	57.2	65.2	6	6	8	5	0	0	35	2	1
5/26	27.1°	118.5°	0000	98	02	14	01	1	1018.6	7	1.5	64.4	57.0	65.5	2	2	1	5	0	0	02	2	1
5/26	27.7°	118.4°	0600	98	01	18	02	0	1019.0	1	0.6	62.9	57.3	65.0	3	X	X	X	X	X	36	2	X
5/26	28.6°	118.2°	1200	98	35	15	03	1	1018.3	6	0.7	61.4	56.8	64.1	7	7	8	5	0	0	02	2	0
5/26	29.5°	118.0°	1800	98	34	14	03	2	1018.3	0	0.3	61.2	56.5	64.0	8	8	5	5	X	X	34	2	1
5/27	30.4°	117.9°	0000	98	33	18	02	2	1016.3	7	1.4	61.0	56.5	62.9	8	8	5	5	X	X	34	3	2
5/27	31.2°	117.7°	0600	98	33	17	02	2	1016.3	1	0.5	59.2	54.8	60.7	8	X	X	X	X	X	34	3	4
5/27	32.0°	117.5°	1200	98	33	13	02	2	1015.2	7	0.2	59.9	54.3	62.4	8	8	5	5	X	X	34	2	1
5/31	32.5°	118.2°	0000	98	33	14	02	0	1013.5	7	1.2	60.9	56.8	62.8	1	1	1	5	0	0	31	2	1
5/31	32.5°	118.4°	0600	98	29	12	02	0	1015.2	1	1.0	58.8	55.4	61.8	X	X	X	X	X	X	29	2	1
5/31	32.5°	118.3°	1200	98	29	09	03	1	1015.9	3	0.2	58.4	54.0	61.9	7	7	8	5	0	0	29	2	0
5/31	32.5°	119.1°	1800	98	30	08	02	2	1018.3	1	0.8	57.7	53.8	61.2	8	8	5	5	X	X	29	2	1
6/1	32.3°	119.4°	0000	98	29	13	02	2	1016.9	6	1.0	59.1	54.8	60.0	8	8	5	5	X	X	29	3	1
6/1	32.1°	119.6°	0600	98	31	14	02	2	1017.6	2	1.0	58.6	55.2	60.2	8	8	X	X	X	X	30	2	1
6/1	32.1°	119.6°	1200	98	33	15	02	2	1016.9	4	0.0	57.8	54.8	60.0	8	8	5	5	X	X	32	2	1
6/1	32.1°	119.8°	1800	98	33	13	02	2	1019.0	2	0.6	57.9	54.2	59.6	8	8	5	5	X	X	33	3	2
6/2	32.1°	120.6°	0000	98	33	13	01	2	1018.0	7	1.2	59.3	55.2	59.7	6	6	8	5	0	0	33	3	2
6/2	32.1°	121.5°	0600	98	34	15	03	2	1018.6	1	1.1	58.9	53.9	60.2	8	X	X	X	X	X	34	3	2
6/2	32.1°	122.6°	1200	98	34	16	02	2	1017.6	6	0.7	57.7	52.2	60.0	8	8	5	5	X	X	34	3	2
6/2	32.0°	123.4°	1800	98	35	13	02	2	1020.3	2	0.9	59.2	54.0	60.1	8	8	5	5	X	X	35	2	2
6/2	31.7°	123.6°	2100	98	34	14	02	2	1020.3	8	0.2	60.3	54.0	61.1	8	8	8	5	X	X	34	2	2
6/3	31.5°	123.9°	0000	98	33	14	01	2	1019.6	6	0.4	59.8	54.5	61.2	7	7	8	5	0	0	32	2	2

Table 1.--Summary of weather observations (USWB 1210-F), Hugh M. Smith cruise 52 - con.

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. cor. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
6/3	31.3°	124.2°	0300	98	34	15	02	2	1019.6	5	0.0	60.0	54.7	61.0	8	8	5	5	X	X	32	2	2
6/3	31.1°	124.5°	0600	98	34	13	02	2	1021.0	2	1.0	60.0	53.6	61.7	8	X	X	X	X	X	32	2	2
6/3	31.1°	125.0°	1200	98	35	13	02	2	1019.3	7	0.5	59.7	54.7	61.4	8	8	5	5	X	X	33	2	2
6/3	31.0°	125.0°	1800	98	36	12	01	1	1021.3	2	0.7	60.3	55.9	61.9	3	3	2	5	0	0	36	2	2
6/4	31.1°	124.9°	0000	98	36	11	03	1	1020.0	7	1.2	62.3	59.3	62.3	7	7	5	5	0	0	01	2	3
6/4	31.4°	124.9°	0600	98	33	14	02	2	1020.7	3	0.9	61.6	59.2	62.2	7	X	X	X	X	X	33	2	1
6/4	31.0°	125.0°	1200	98	01	13	02	2	1020.3	6	0.6	60.9	58.3	61.4	8	X	X	X	X	X	01	2	1
6/4	30.7°	124.5°	1800	98	36	14	80	8	1021.0	1	0.1	60.9	58.6	61.9	2	2	9	5	0	0	02	2	1
6/5	30.5°	123.9°	0000	98	36	13	80	8	1019.6	7	1.0	61.1	59.3	61.8	7	7	9	5	0	0	02	2	1
6/5	30.5°	123.6°	0600	98	35	15	01	8	1019.6	3	0.4	61.3	58.0	62.2	1	X	X	X	X	X	01	2	1
6/5	30.5°	123.6°	1200	98	01	14	03	1	1018.6	6	0.6	60.0	57.6	62.0	8	X	X	X	X	X	01	2	2
6/5	30.4°	123.3°	1800	98	33	17	15	8	1019.3	1	0.2	61.9	59.7	62.8	8	8	7	5	X	X	35	3	5
6/6	30.3°	122.6°	0000	97	35	17	50	5	1017.3	7	1.4	61.9	59.9	63.0	7	7	7	5	0	0	36	4	6
6/6	30.3°	122.0°	0600	97	36	13	51	5	1016.3	3	0.2	60.8	59.6	62.2	8	X	X	X	X	X	36	4	5
6/6	30.3°	121.4°	1200	98	36	16	28	4	1015.9	4	0.0	60.6	57.7	61.8	6	6	7	3	0	0	33	4	3
6/6	30.0°	120.9°	1800	98	35	15	01	1	1016.6	2	0.7	62.3	59.1	62.1	3	3	1	5	0	0	33	4	3
6/7	30.0°	120.9°	0000	98	32	18	05	0	1015.2	7	1.3	63.2	58.9	62.2	0	0	0	9	0	0	32	4	4
6/7	29.9°	120.3°	0600	98	35	19	00	0	1016.3	2	0.8	61.4	57.4	61.25	0	0	0	9	0	0	34	4	6
6/7	29.8°	119.6°	1200	98	35	18	03	0	1013.9	7	1.0	60.7	57.3	61.0	2	2	1	5	0	0	35	4	5
6/7	29.8°	118.9°	1800	98	34	21	02	0	1014.9	2	0.4	61.4	57.8	61.6	1	1	1	5	0	0	34	4	7
6/8	29.8°	118.1°	0000	98	34	22	02	0	1012.9	7	1.6	63.7	59.3	63.1	1	1	1	5	0	0	34	4	8
6/8	29.4°	117.9°	0600	98	34	19	02	0	1012.9	2	1.7	61.8	58.3	63.8	3	X	X	X	X	X	34	4	6
6/8	29.6°	118.0°	1200	98	35	18	03	1	1012.5	5	0.0	60.7	57.0	63.5	7	7	5	5	0	0	35	4	5
6/8	29.6°	117.9°	1800	98	31	19	02	2	1013.5	2	0.1	62.1	57.9	63.8	7	7	5	5	0	0	31	4	5
6/9	29.7°	117.9°	0000	98	33	17	02	2	1012.5	7	0.9	63.7	57.9	63.9	6	6	5	5	0	0	33	4	6
6/9	29.1°	117.9°	0600	98	33	18	02	2	1013.9	1	0.9	62.5	58.9	64.2	7	X	X	X	X	X	33	4	5
6/9	28.9°	118.1°	1200	98	01	07	01	1	1012.5	7	0.6	62.9	58.9	64.7	3	3	5	5	0	0	34	3	7
6/9	29.1°	118.2°	1800	98	32	17	03	1	1013.9	2	0.4	61.9	58.3	64.7	6	6	5	5	0	0	32	3	4
6/10	28.7°	118.0°	0000	98	27	07	01	1	1011.9	7	1.8	65.5	59.4	64.9	1	1	5	5	0	0	32	3	4
6/10	28.8°	118.0°	0600	98	35	17	03	1	1012.2	3	0.6	62.8	59.7	64.8	7	X	X	X	X	X	34	3	3

Table 1.--Summary of weather observations (USWB 1210-F), Hugh M. Smith cruise 52 - con.

					Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Direction	Speed (kn.)	Present	Past	Bar. cor. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
6/10	28.8°	118.0°	1200	98	35	15	02	2	1010.8	6	0.7	61.8	58.7	64.2	8	8	5	5	X	X	34	3	3
6/10	29.0°	117.5°	1800	98	34	09	02	2	1012.9	1	1.0	62.8	58.4	64.0	8	8	5	5	X	X	34	4	4
6/11	29.5°	117.0°	0000	98	32	14	02	2	1011.2	7	1.4	63.0	58.7	63.7	7	7	5	5	0	0	33	4	5
6/11	29.4°	117.0°	0600	98	35	11	02	2	1012.2	1	0.9	61.4	57.8	63.4	7	7	5	5	0	0	34	4	4
6/11	29.1°	116.9°	1200	98	31	08	02	2	1011.2	8	0.7	60.6	57.3	63.1	8	8	5	5	X	X	32	3	2
6/11	29.1°	117.1°	1800	98	32	06	02	2	1013.2	0	0.4	62.1	57.8	63.9	8	8	5	5	X	X	31	5	5
6/12	28.7°	117.6°	0000	98	31	05	02	2	1012.9	7	0.2	65.2	59.6	65.8	7	7	5	5	0	0	31	5	7
6/12	28.6°	118.3°	0600	98	35	07	02	2	1013.9	2	1.2	62.2	57.9	64.6	7	7	5	5	0	0	31	5	5
6/12	28.4°	119.1°	1200	98	29	09	02	2	1013.9	5	0.0	61.6	56.7	64.1	8	8	5	5	X	X	32	4	4
6/12	28.2°	119.5°	1800	98	29	05	02	2	1016.3	1	0.8	63.2	57.2	64.2	8	8	5	5	X	X	32	4	4
6/13	28.2°	119.7°	0000	98	30	08	01	2	1014.6	8	1.2	64.3	57.9	65.1	4	4	5	5	0	0	31	4	5
6/13	28.1°	120.1°	0600	98	33	08	03	2	1015.6	2	1.0	62.8	57.3	65.8	6	6	5	5	0	0	32	3	3
6/13	27.8°	121.1°	1200	98	33	10	02	2	1015.2	5	0.0	62.1	56.7	65.8	7	7	5	5	0	0	32	3	3
6/13	27.6°	121.6°	1800	98	02	09	02	2	1016.9	1	0.5	63.9	58.4	64.7	8	8	5	5	X	X	04	2	2
6/14	27.4°	122.0°	0000	98	01	15	02	2	1015.2	7	1.0	63.9	59.6	65.4	7	7	8	5	0	0	35	3	3
6/14	27.5°	122.3°	0600	98	36	10	02	2	1016.3	1	0.9	62.6	57.3	64.6	8	8	5	5	X	X	36	3	2
6/14	27.6°	122.3°	1200	98	35	14	02	2	1014.9	6	0.8	62.3	58.6	64.8	8	8	5	5	X	X	35	3	3
6/14	27.5°	122.1°	1800	98	01	17	01	2	1015.6	4	0.0	63.6	58.6	64.8	4	4	1	5	0	0	34	3	4
6/15	27.5°	122.2°	0000	98	01	20	01	1	1013.9	7	1.0	63.9	59.3	64.5	2	2	1	5	0	0	01	3	5
6/15	28.1°	121.9°	0600	98	01	18	03	1	1014.6	1	1.0	62.6	59.2	64.4	4	4	1	5	0	0	02	3	6
6/15	28.5°	121.6°	1200	98	01	19	02	2	1013.5	6	0.8	62.2	58.2	65.0	4	4	8	5	0	0	02	3	6
6/15	28.9°	121.3°	1800	98	36	19	02	2	1016.3	1	0.9	62.7	58.0	64.2	5	5	8	5	0	0	36	3	6
6/16	29.4°	121.0°	0000	98	35	19	02	2	1014.6	8	1.0	62.0	57.4	64.5	5	5	8	5	0	0	35	3	6
6/16	29.4°	120.6°	0600	98	35	20	01	1	1014.2	2	0.2	60.2	56.8	62.1	3	3	8	5	0	0	36	3	8
6/16	30.5°	119.7°	1200	98	35	22	03	1	1013.5	5	0.2	59.2	55.8	61.3	5	5	8	5	0	0	35	3	7
6/16	30.7°	119.2°	1800	98	35	23	01	1	1013.9	6	0.5	61.1	57.0	61.8	1	1	1	5	0	0	36	3	7
6/17	30.8°	119.0°	0000	98	36	22	02	0	1011.5	7	1.6	63.0	59.7	62.2	1	1	1	5	0	0	36	3	9
6/17	31.2°	119.3°	0600	98	33	20	02	0	1012.9	1	0.6	61.0	56.7	60.7	0	0	0	9	0	0	34	3	8
6/17	31.1°	119.3°	1200	98	31	20	02	0	1011.5	4	0.0	60.5	57.0	61.0	0	0	0	9	0	0	34	3	5
6/17	30.8°	119.2°	1800	98	32	19	02	0	1012.2	4	0.0	62.6	58.8	62.4	0	0	0	9	0	0	32	3	7

Table 1.--Summary of weather observations (USWB 1210-F), Hugh M. Smith cruise 52 - con.

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. cor. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
6/18	31.0°	119.2°	0000	98	33	18	02	0	1009.8	7	0.8	62.9	59.6	62.4	0	0	0	9	0	0	34	3	6
6/18	31.4°	119.3°	0600	98	33	15	02	0	1010.2	2	0.6	60.9	58.9	61.0	0	0	0	9	0	0	34	4	5
6/18	31.2°	119.0°	1200	98	29	15	02	0	1009.5	7	0.7	61.8	59.8	61.5	0	0	0	9	0	0	31	2	3
6/18	31.5°	118.5°	1800	98	31	09	03	1	1011.2	3	1.1	61.2	57.7	62.4	8	8	5	5	X	X	30	2	2
6/19	31.8°	117.9°	0000	98	27	07	02	2	1009.5	6	1.0	62.6	59.6	65.8	7	7	5	5	0	0	28	2	2
6/19	32.0°	117.8°	0600	98	35	05	02	2	1010.8	1	1.2	63.4	61.2	65.2	7	7	5	5	0	0	33	2	0
6/19	32.0°	117.8°	1200	98	32	10	02	2	1010.2	7	0.2	59.3	57.2	64.7	7	7	5	5	0	0	31	2	0
6/19	32.6°	117.8°	1800	97	28	09	02	2	1011.9	1	1.0	63.2	60.7	64.8	8	8	5	5	X	X	29	2	1

Table 2.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 52

Ser. No.	Time, (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp., (° F.)	Wind		Air temp.		Barometer, (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal., (‰)	Surf. PO4-P, µg·at./1.
						Dir., (°T.)	Force, (kn.)	Dry bulb, (°F.)	Wet bulb, (°F.)			Type	Cover			Dir. (°T.)	Amt.		
1	1745	4/29	22°48'	155°58'	72.2	13	19	71.2	68.7	1022	95	8,7	6	7	3	11	1	-	-
2	2300	4/29	23°12'	155°28'	73.0	07	14	75.2	69.8	1021	01	8,6	1	7	2	07	1	35.00	0.34
3	0600	4/30	23°50'	154°41'	73.1	08	15	73.0	68.8	1021	02	9,6	1	7	3	08	2	35.00	0.42
4	1200	4/30	24°23'	153°56'	73.1	11	16	72.2	67.5	1021	02	8	1	7	2	10	1	34.89	0.28
5	1800	4/30	24°58'	153°11'	72.7	10	16	73.7	66.4	1022	25	8,9	2	7	2	10	1	34.87	0.42
6	2200	4/30	25°22'	152°44'	73.2	09	13	73.4	66.4	1022	02	8	1	7	2	10	1	34.75	0.81
7	0600	5/1	26°10'	151°49'	72.2	10	14	72.4	65.2	1022	02	9,8	1	7	2	06	1	34.97	0.44
8	1205	5/1	26°47'	151°02'	71.2	11	09	71.5	67.8	1021	02	8	1	7	2	10	1	35.07	0.15
9	1800	5/1	27°25'	150°16'	68.8	11	17	70.4	65.0	1022	15	8,6	6	7	3	11	2	35.19	0.36
10	2155	5/1	27°48'	149°48'	68.8	10	14	71.0	64.4	1023	02	6	6	7	3	10	2	35.15	0.49
11	0600	5/2	28°40'	148°48'	68.0	09	15	69.0	61.8	1024	02	8	2	7	2	10	2	35.11	0.49
12	1200	5/2	29°17'	148°02'	67.7	11	14	66.9	59.7	1024	00	X	X	7	2	10	2	35.17	0.12
13	1800	5/2	29°55'	147°14'	67.1	12	14	66.7	59.3	1027	03	6	7	7	2	12	1	35.09	0.26
14	2200	5/2	30°20'	146°42'	66.3	10	10	67.8	59.0	1027	01	1,8	2	7	2	10	1	34.97	0.32
15	0600	5/3	31°08'	145°40'	64.9	10	13	64.7	57.8	1028	02	8,1,2	4	7	1	02	1	34.61	0.58
16	1203	5/3	31°46'	144°50'	65.2	11	12	63.8	57.4	1027	03	8,1,2	5	7	1	06	1	34.86	0.20
17	1800	5/3	32°22'	144°02'	63.4	14	10	63.4	55.6	1029	03	8,1,2	6	7	1	10	1	34.29	0.22
18	2055	5/3	32°36'	143°45'	64.1	15	08	65.6	56.0	1030	02	8,1,2	7	7	1	02	2	34.43	0.20
19	0000	5/4	32°51'	143°24'	63.8	15	11	64.8	57.5	1029	01	8,1,2	4	7	1	05	2	34.30	0.22
20	0600	5/4	33°18'	142°47'	62.7	16	10	63.0	57.2	1030	02	8,1,2	4	7	1	05	2	34.12	0.15
21	1200	5/4	33°41'	142°11'	61.7	16	12	61.8	56.3	1028	01	1,6	1	7	1	15	1	34.15	0.22
22	1800	5/4	34°08'	141°34'	61.4	18	11	62.6	56.8	1029	03	1,8,6	3	7	1	02	2	34.01	0.17
23	2055	5/4	34°22'	141°14'	62.1	20	11	63.8	57.3	1029	03	1,2,8	7	7	1	02	1	34.06	1.65
24	0000	5/5	34°36'	140°58'	62.3	23	10	64.2	58.0	1029	02	2,6	7	7	1	22	1	34.04	-
25	0340	5/5	34°48'	140°42'	62.1	22	08	63.4	57.4	1029	03	6,2	8	7	1	21	1	34.04	0.20
26	0350	5/5	34°48'	140°42'	62.1	22	08	63.4	57.4	1029	03	6,2	8	7	1	21	1	34.04	0.20
27	1540	5/5	34°50'	140°42'	61.9	23	10	63.2	59.8	1030	01	None	0	7	1	23	1	-	-
28	1800	5/5	35°02'	140°30'	61.0	25	07	62.7	59.5	1031	03	2,6,8	1	7	1	29	1	33.89	0.31
29	2055	5/5	35°16'	140°14'	62.0	22	06	65.6	60.7	1032	03	1,2,8,6	3	7	1	29	2	33.90	0.33
30	0000	5/6	35°28'	139°54'	62.9	24	06	65.4	60.4	1031	03	1,2,8,5	2	7	1	29	2	33.93	0.59

Table 2.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 52 - con.

Ser. No.	Time, (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp., (°F.)	Wind		Air temp.		Barometer, (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal., (‰)	Surf. PO$_4$-P, µg.at./1.
						Dir., (°T.)	Force, (kn.)	Dry bulb, (°F.)	Wet bulb, (°F.)			Type	Cover			Dir. (°T.)	Amt.		
31	0555	5/6	35°54'	139°15'	60.8	24	06	61.3	59.8	1032	03	1,2,8	3	7	1	29	2	33.75	0.36
32	1200	5/6	36°24'	138°37'	60.6	23	03	60.4	59.6	1031	01	X	1	7	X	X	X	33.71	0.34
33	1745	5/6	36°48'	138°00'	61.3	26	03	62.7	59.4	1032	03	5,1,2,8	2	7	0	30	2	33.73	0.42
34	1800	5/6	36°48'	138°02'	61.3	26	03	62.7	59.4	1032	03	5,1,2,8	2	7	0	30	2	34.73	0.42
35	0032	5/7	36°49'	138°04'	62.0	25	07	65.3	59.3	1030	02	1,2,3,8	3	7	0	28	2	-	-
36	0600	5/7	37°14'	137°30'	61.0	23	06	61.9	58.8	1030	02	1,2,4,8	3	7	0	29	2	33.57	0.31
37	1200	5/7	37°45'	136°49'	58.8	23	09	62.6	58.9	1027	02	X	3	7	0	XX	X	33.46	0.34
38	1800	5/7	38°15'	136°10'	58.1	20	07	62.4	59.8	1027	03	5,2,6,9	7	7	1	28	2	33.41	0.36
39	2052	5/7	38°28'	135°52'	58.4	23	06	62.9	59.6	1027	02	5,2,6,9	7	7	1	28	2	33.17	0.44
40	0000	5/8	38°41'	135°32'	58.6	23	06	64.7	60.2	1026	01	8,4,5,1, 2	6	7	1	28	2	33.13	0.52
41	0345	5/8	38°55'	135°12'	57.5	22	05	63.7	59.9	1027	01	1,2,4,8	3	7	1	28	5	33.21	0.55
42	0350	5/8	38°55'	135°12'	57.5	22	05	63.7	59.9	1027	01	1,2,4,8	3	7	1	28	5	33.21	0.55
43	1559	5/8	38°48'	135°06'	56.9	35	15	56.9	54.2	1031	20	7,8	8	7	2	35	2	-	-
44	2055	5/8	38°29'	134°40'	57.5	35	13	57.7	54.1	1033	02	7,8	7	7	2	35	1	33.12	0.36
45	0000	5/9	38°15'	134°22'	58.0	35	14	57.6	52.7	1032	02	6	7	7	2	35	1	33.27	0.30
46	0555	5/9	37°46'	133°45'	58.25	01	15	56.6	51.2	1033	01	1,2,6	6	7	3	33	5	33.16	0.64
47	1200	5/9	37°18'	133°10'	59.4	01	08	55.8	50.6	1031	01	1,2,6	3	7	2	XX	X	33.28	0.58
48	1800	5/9	36°51'	132°34'	60.6	36	14	59.0	53.8	1032	03	6	7	7	3	35	2	33.47	0.30
49	2052	5/9	36°41'	132°21'	61.3	35	11	59.8	54.1	1031	03	6	8	7	4	35	4	33.62	0.51
50	2358	5/9	36°32'	132°10'	61.0	36	12	59.8	54.3	1029	02	6	8	7	4	32	4	33.58	0.97
51	0440	5/10	36°42'	132°24'	61.2	35	14	59.5	57.0	1028	50	7,6	8	5	4	32	4	33.65	0.34
52	0448	5/10	36°42'	132°24'	61.2	35	14	59.5	57.0	1028	50	7,6	8	5	4	32	4	33.65	0.34
53	1600	5/10	36°39'	132°24'	61.0	36	13	56.9	55.3	1024	80	7,6	7	7	2	36	1	-	-
54	2102	5/10	36°18'	131°49'	60.6	04	12	59.5	56.5	1023	01	6	6	7	2	02	1	33.58	0.55
55	0000	5/11	36°03'	131°32'	60.25	05	12	59.4	54.2	1020	02	7	7	7	2	04	1	33.57	1.26
56	0600	5/11	35°35'	130°59'	59.8	07	12	57.3	54.5	1018	01	X	3	7	2	05	1	33.22	0.51
57	1205	5/11	35°09'	130°22'	60.0	04	12	57.8	55.0	1016	01	1,2	2	7	2	05	1	33.36	0.74
58	1807	5/11	34°41'	129°44'	59.1	04	14	60.8	55.8	1015	01	8,1,2	2	7	3	35	4	33.16	0.38
59	2019	5/11	34°32'	129°32'	59.7	03	12	60.3	55.7	1014	02	8	1	7	3	36	4	33.20	0.51
60	0004	5/12	34°14'	129°09'	60.9	04	14	59.6	56.6	1012	02	8	2	7	3	35	4	33.30	0.35

Table 2.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 52 - con.

Ser. No.	Time, (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp., (°F.)	Wind		Air temp.		Barometer, (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal., (‰)	Surf. PO_4-P, µg.at./l.
						Dir., (°T.)	Force, (kn.)	Dry bulb, (°F.)	Wet bulb, (°F.)			Type	Cover			Dir. (°T.)	Amt.		
61	0603	5/12	33°48'	128°36'	60.2	07	08	58.6	55.7	1012	03	X	3	7	3	35	4	33.20	0.38
62	1807	5/15	37°24'	123°02'	51.8	32	28	55.6	51.2	1021	02	X	0	7	5	30	3	-	-
63	1803	5/16	35°58'	125°46'	57.1	32	13	57.8	54.1	1022	03	1,2,8	6	7	3	32	1	-	-
64	0000	5/17	35°12'	126°26'	59.6	31	15	61.6	56.2	1022	02	1,2,8	6	7	2	32	1	-	-
65	0602	5/17	34°24'	127°04'	59.2	31	14	61.3	56.9	1022	03	2	7	7	2	31	1	-	-
66	1200	5/17	33°42'	127°53'	61.0	31	16	61.3	57.8	1021	01	X	0	7	2	31	1	33.28	-
67	1639	5/17	33°18'	127°58'	60.9	35	17	63.6	59.3	1023	03	9,8,4	6	7	2	30	1	-	0.45
68	1647	5/17	33°18'	127°58'	60.9	35	17	63.6	59.3	1023	03	9,8,4	6	7	2	30	1	33.28	0.45
69	2307	5/17	33°23'	128°00'	61.8	36	09	65.8	55.7	1024	02	1,2,4,8	5	7	1	36	1	-	-
70	0603	5/18	32°46'	127°13'	61.5	36	07	61.6	56.8	1024	01	8	1	7	1	36	1	33.40	0.32
71	1205	5/18	32°06'	126°21'	60.9	36	10	59.9	55.1	1022	03	X	7	7	1	36	1	33.59	0.33
72	1803	5/18	31°36'	125°43'	61.25	01	16	62.0	56.0	1024	01	8	2	7	2	34	1	33.52	0.33
73	1954	5/18	31°28'	125°33'	61.9	01	17	61.3	55.0	1024	01	8,4	1	7	2	36	4	33.69	0.22
74	0003	5/19	31°10'	125°13'	62.0	36	21	61.3	56.2	1022	02	4,8,9	6	7	3	35	4	33.66	0.27
75	0600	5/19	30°44'	124°48'	61.8	01	21	60.6	53.7	1023	02	8,6	6	7	3	02	4	33.59	0.33
76	1203	5/19	30°10'	124°21'	62.0	01	23	60.2	54.9	1020	02	8,6	5	7	3	02	4	33.60	0.17
77	1805	5/19	29°37'	124°07'	62.9	36	26	63.8	58.0	1022	01	8,9	4	7	3	02	6	33.72	0.31
78	2357	5/19	29°04'	123°43'	63.5	02	24	63.6	58.7	1019	01	8	3	7	3	36	4	33.88	0.35
79	2000	5/20	29°39'	123°56'	63.0	36	23	62.6	58.6	1020	80	8,9	6	7	3	36	4	-	-
80	1635	5/21	28°53'	123°25'	63.8	36	14	61.8	55.6	1018	03	6	8	7	3	34	4	34.10	0.32
81	1642	5/21	28°55'	123°26'	63.8	36	14	61.8	55.6	1018	03	6	8	7	3	34	4	34.10	0.32
82	2305	5/21	28°55'	123°28'	64.0	34	15	62.8	56.7	1017	02	6	7	7	3	34	4	-	-
83	0603	5/22	28°20'	122°58'	63.7	35	09	61.9	56.2	1017	02	6	7	7	2	34	1	33.96	0.29
84	1157	5/22	27°46'	122°29'	64.7	35	06	61.8	56.3	1015	02	6	8	7	1	35	1	34.28	0.25
85	1643	5/22	27°21'	122°08'	64.7	32	07	63.6	56.7	1016	02	6	8	7	1	32	1	34.28	0.26
86	1651	5/22	27°22'	122°08'	64.7	32	07	63.6	56.7	1016	02	6	8	7	1	32	1	34.28	0.26
87	2303	5/22	27°24'	122°09'	65.1	34	11	64.0	57.6	1015	02	6	8	7	1	34	1	-	-
88	2310	5/22	27°24'	122°09'	65.1	34	11	64.0	57.6	1015	02	6	8	7	1	34	1	-	-
89	0307	5/23	27°07'	122°03'	65.0	33	10	63.7	55.3	1015	02	6,8	8	7	1	33	1	34.16	0.28
90	0312	5/23	27°07'	122°03'	65.0	33	10	63.7	55.3	1015	02	6,8	8	7	1	33	1	34.16	0.28

Table 2.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 52 - con.

Ser. No.	Time, (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp., (°F.)	Wind		Air temp.		Baro-meter, (mb.)	Wea-ther	Clouds		Visibility	Sea	Swell		Surf. sal., (‰)	Surf. PO_4-P, µg at./l.
						Dir., (°T.)	Force, (kn.)	Dry bulb, (°F.)	Wet bulb, (°F.)			Type	Cover			Dir. (°T.)	Amt.		
91	1455	5/23	26°59'	121°59'	64.9	01	10	59.7	57.3	1016	16	6,8,9	4	7	1	33	1	-	-
92	1803	5/23	26°53'	121°50'	65.0	36	08	61.8	58.3	1018	15	6,8,4,9	3	7	1	36	1	34.12	0.26
93	2020	5/23	26°52'	121°34'	66.0	03	03	63.0	58.0	1018	15	6,5,8,9	2	7	1	36	3	34.06	0.26
94	0003	5/24	26°56'	121°10'	66.1	03	05	62.3	57.7	1017	15	6,5,8,9	3	7	1	01	1	34.03	0.29
95	0230	5/24	27°00'	120°56'	65.8	01	07	62.9	57.6	1017	15	2,6,4,8,9	3	7	1	35	1	34.00	0.27
96	0236	5/24	27°00'	120°56'	65.8	01	07	62.9	57.6	1017	15	2,6,4,8,9	3	7	1	35	1	34.00	0.27
97	1448	5/24	26°58'	120°56'	65.1	35	07	63.6	55.3	1019	02	6	7	7	1	36	1	-	-
98	1802	5/24	26°59'	120°34'	65.3	36	07	64.8	55.2	1020	02	6,8	7	7	1	35	1	34.02	0.26
99	2020	5/24	27°00'	120°18'	65.9	36	10	64.8	56.4	1020	02	6,8	7	7	1	36	1	34.06	0.26
100	0002	5/25	27°00'	119°48'	65.9	35	07	64.7	55.3	1019	02	6,8	6	7	1	35	1	33.98	0.31
101	0239	5/25	27°00'	119°31'	65.5	35	11	64.2	55.3	1018	01	6,8	2	7	1	35	1	33.97	0.29
102	0246	5/25	27°00'	119°31'	65.5	35	11	64.2	55.3	1018	01	6,8	2	7	1	35	1	33.97	0.29
103	1407	5/25	26°58'	119°32'	65.0	36	17	64.0	58.0	1020	02	6,8	3	7	2	35	1	-	-
104	1805	5/25	27°02'	119°07'	65.2	02	13	64.8	57.2	1021	02	6,8	6	7	2	35	1	34.03	0.28
105	1953	5/25	27°04'	118°54'	65.7	02	13	64.8	58.0	1021	01	8,5	3	7	2	36	1	34.05	0.27
106	2335	5/25	27°04'	118°27'	65.5	02	14	64.4	57.0	1019	01	8	2	7	2	02	1	34.03	0.30
107	0601	5/26	27°44'	118°22'	64.0	01	18	62.9	57.3	1019	02	X	3	7	2	36	X	33.81	0.30
108	1205	5/26	28°39'	118°14'	64.1	35	15	61.4	56.8	1018	03	8,6	7	7	2	35	1	33.88	0.30
109	1744	5/26	29°32'	118°03'	64.0	34	14	61.2	56.5	1018	03	6	8	7	2	35	1	33.73	0.32
110	1955	5/26	29°51'	117°59'	62.2	34	15	61.0	56.5	1018	02	6	8	7	2	34	1	33.61	0.32
111	0003	5/27	30°23'	117°53'	62.9	33	18	61.0	56.5	1016	02	6	8	7	3	34	1	33.64	0.30
112	0602	5/27	31°10'	117°44'	61.0	33	17	59.2	54.8	1016	02	X	8	7	3	34	3	33.60	0.32
113	1200	5/27	32°91'	117°30'	62.4	33	13	59.9	54.3	1015	02	6	8	7	2	34	1	33.69	0.31
114	1857	5/30	32°30'	117°36'	65.2	29	07	60.3	55.2	1016	02	X	8	7	1	28	1	-	-
115	1952	5/30	32°30'	117°44'	64.1	30	12	59.8	55.0	1016	02	X	0	7	1	28	1	33.70	0.32
116	0000	5/31	32°30'	118°10'	62.8	31	14	60.9	56.8	1014	02	8	1	7	1	31	1	33.67	0.37
117	0245	5/31	32°30'	118°20'	62.1	29	12	59.6	55.5	1014	02	8,1,2	1	7	1	28	1	33.67	0.34
118	0250	5/31	32°30'	118°20'	62.1	29	12	59.6	55.5	1014	02	8,1,2	1	7	1	28	1	33.67	0.34
119	1500	5/31	32°33'	118°26'	62.0	28	08	58.1	54.2	1018	02	6	8	7	1	29	1	33.69	0.37
120	1507	5/31	32°33'	118°26'	62.0	28	08	58.1	54.2	1018	02	6	8	7	1	29	1	33.69	0.37

Table 2.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 52 - con.

Ser. No.	Time, (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp., (°F.)	Wind		Air temp.		Barometer, (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal., (‰)	Surf. PO_4-P, µg.at./l.
						Dir., (°T.)	Force, (kn.)	Dry bulb, (°F.)	Wet bulb, (°F.)			Type	Cover			Dir. (°T.)	Amt.		
121	1800	5/31	32°33'	118°48'	61.2	30	08	57.7	53.8	1018	02	6	8	7	1	29	1	33.65	0.39
122	1951	5/31	32°33'	119°06'	58.8	30	07	58.8	54.3	1018	02	6	8	7	0	29	1	33.58	0.48
123	0000	6/1	32°18'	119°26'	60.0	29	13	59.1	54.8	1017	02	6	8	7	0	29	1	33.59	0.37
124	0240	6/1	32°08'	119°36'	60.0	30	17	58.0	54.7	1016	02	6	8	7	1	29	1	33.48	0.86
125	0245	6/1	32°08'	119°36'	60.0	30	17	58.0	54.7	1016	02	6	8	7	1	29	1	33.48	0.86
126	1458	6/1	32°05'	119°28'	60.0	31	13	57.4	53.7	1019	02	6	8	7	1	31	1	-	-
127	1755	6/1	32°05'	119°50'	59.6	33	13	57.9	54.2	1019	02	6	8	7	2	33	1	33.53	0.37
128	1956	6/1	32°04'	120°04'	59.8	34	10	58.3	54.2	1019	02	6	8	7	2	33	1	33.46	0.41
129	0002	6/2	32°06'	120°36'	59.7	33	13	59.3	55.2	1018	01	6,8	6	7	2	33	1	33.51	0.43
130	0600	6/2	32°07'	121°32'	60.2	34	15	58.9	53.9	1019	03	X	8	7	2	34	1	33.40	0.37
131	1200	6/2	32°08'	122°36'	60.0	34	16	57.7	52.2	1017	02	6	8	7	2	34	1	33.34	0.89
132	1802	6/2	31°58'	123°23'	60.1	35	13	59.2	54.0	1020	02	6	8	7	1	35	1	33.32	0.36
133	1951	6/2	31°50'	123°33'	61.0	36	11	59.9	54.2	1021	02	6,8	8	7	1	35	1	33.54	0.37
134	0001	6/3	31°30'	123°56'	61.2	33	14	59.8	54.5	1020	01	6,8	7	7	1	32	1	33.57	0.34
135	0602	6/3	31°09'	124°32'	61.7	34	13	60.0	53.6	1021	02	X	8	7	1	32	1	33.60	0.50
136	1652	6/3	31°04'	124°54'	61.7	01	16	60.3	55.4	1021	01	8	5	7	1	01	1	33.59	0.38
137	1657	6/3	31°05'	124°55'	61.7	01	16	60.3	55.4	1021	01	8	5	7	1	01	1	33.59	0.38
138	2316	6/3	31°07'	124°56'	62.25	36	11	62.3	59.3	1020	02	6	7	7	1	01	1	-	-
139	1204	6/4	30°51'	125°04'	61.4	01	13	60.9	58.3	1020	02	X	8	7	1	01	1	-	-
140	1758	6/4	30°42'	124°32'	61.9	36	14	60.9	58.6	1021	80	9,8	2	7	1	02	1	33.53	-
141	1952	6/4	30°39'	124°20'	61.5	35	11	61.3	58.7	1021	15	9,8	3	7	1	36	1	33.48	0.46
142	0003	6/5	30°32'	123°51'	61.8	36	13	61.1	59.3	1020	80	8,9	7	7	1	02	1	33.48	0.41
143	0242	6/5	30°29'	123°38'	62.2	36	13	60.4	58.2	1019	16	7,8,9	7	7	1	02	1	33.54	0.37
144	0248	6/5	30°29'	123°38'	62.2	36	13	60.4	58.2	1019	16	7,8,9	7	7	1	02	1	33.54	0.37
145	1456	6/5	30°24'	123°35'	62.8	34	13	60.4	58.6	1019	80	7	8	7	2	35	3	-	-
146	1814	6/5	30°22'	123°20'	62.8	33	17	61.9	59.7	1019	15	8	8	7	2	35	3	33.68	-
147	1958	6/5	30°20'	123°06'	62.8	36	15	62.2	59.8	1019	16	8	7	7	2	36	3	33.69	0.35
148	0004	6/6	30°16'	122°39'	63.0	35	17	61.9	59.9	1017	50	8	7	6	2	36	3	33.72	0.54
149	0546	6/6	30°16'	122°02'	62.2	36	13	60.8	59.6	1016	51	8	8	6	2	36	3	33.56	0.37
150	1204	6/6	30°19'	121°21'	61.8	36	16	60.6	57.7	1016	28	8	6	7	2	33	1	33.55	0.40

Table 2.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 52 - con.

Ser. No.	Time, (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp., (°F.)	Wind		Air temp.		Baro-meter, (mb.)	Wea-ther	Clouds		Visibility	Sea	Swell		Surf. sal., (‰)	Surf. PO_4-P, µg.at./1.
						Dir., (°T.)	Force, (kn.)	Dry bulb, (°F.)	Wet bulb, (°F.)			Type	Cover			Dir. (°T.)	Amt.		
151	1641	6/6	30°01'	120°55'	61.9	34	14	62.1	58.9	1016	01	8	2	7	2	33	3	33.55	0.39
152	1649	6/6	30°01'	120°55'	61.9	34	14	62.1	58.9	1016	01	8	2	7	2	33	3	33.55	0.39
153	2310	6/6	30°00'	120°56'	62.2	33	17	63.1	58.9	1016	02	X	0	7	2	33	4	-	-
154	0542	6/7	29°52'	120°21'	61.25	35	19	61.4	57.4	1016	00	X	0	7	2	34	4	33.47	0.36
155	1200	6/7	29°50'	119°37'	61.0	35	18	60.7	57.3	1014	03	8	2	7	2	35	4	33.56	0.38
156	1810	6/7	29°48'	118°51'	61.6	34	21	61.4	57.8	1015	02	8	1	7	3	34	4	33.50	0.38
157	1958	6/7	29°48'	118°38'	62.0	34	21	62.0	58.4	1014	02	8	1	7	3	34	7	33.49	0.36
158	0006	6/8	29°49'	118°05'	63.1	34	22	63.7	59.3	1013	02	8	1	7	3	34	7	33.65	0.31
159	1644	6/8	29°36'	117°52'	63.6	31	17	62.1	57.4	1014	03	6	6	7	2	31	4	33.81	0.31
160	1656	6/8	29°37'	117°53'	63.6	31	17	62.1	57.4	1014	03	6	6	7	2	31	4	33.81	0.31
161	2333	6/8	29°40'	117°53'	63.9	33	17	63.7	57.9	1012	02	6	6	7	3	32	4	-	-
162	0550	6/9	29°04'	117°56'	64.2	33	18	62.5	58.9	1014	02	X	7	7	3	33	4	33.85	0.32
163	1205	6/9	28°53'	118°06'	64.7	01	07	62.4	58.9	1012	01	6	3	7	2	34	1	33.82	0.30
164	1757	6/9	29°09'	118°11'	64.7	32	17	61.9	58.3	1014	03	6	6	7	2	32	4	33.79	0.32
165	1957	6/9	28°58'	118°02'	64.5	36	16	62.9	58.7	1014	01	6,8	3	7	2	33	4	33.84	0.35
166	2247	6/9	28°43'	117°50'	64.6	27	07	65.5	57.8	1013	03	6	7	7	1	33	2	33.75	0.31
167	0307	6/10	28°51'	117°58'	64.5	35	16	62.8	59.8	1012	02	6	5	7	1	35	2	33.80	0.33
168	0312	6/10	28°51'	117°58'	64.5	35	16	62.8	59.8	1012	02	6	5	7	1	35	2	33.80	0.33
169	1413	6/10	28°48'	117°52'	64.2	35	16	61.9	57.8	1012	02	6	7	7	1	35	2	-	-
170	1755	6/10	29°02'	117°31'	64.0	34	09	62.8	58.4	1013	02	6	8	7	1	34	4	33.88	0.35
171	1952	6/10	29°10'	117°19'	64.1	35	11	63.0	58.6	1012	02	6	8	7	1	34	4	33.83	0.94
172	0003	6/11	29°29'	117°00'	63.7	32	14	63.0	58.7	1011	02	6	8	7	1	33	4	33.70	0.34
173	0240	6/11	29°23'	117°00'	63.5	32	12	61.7	57.4	1012	02	6	7	7	1	32	4	33.69	0.42
174	0246	6/11	29°23'	117°00'	63.5	32	12	61.7	57.4	1012	02	6	7	7	1	32	4	33.69	0.42
175	1446	6/11	29°18'	116°53'	63.3	29	06	60.9	57.3	1013	02	6	8	7	1	32	4	-	-
176	1802	6/11	29°07'	117°04'	63.9	32	06	62.1	57.8	1013	02	6	8	7	1	31	4	33.82	0.35
177	1951	6/11	28°58'	117°14'	64.0	32	08	63.3	59.0	1013	01	6	7	7	1	32	7	33.73	0.49
178	0002	6/12	28°44'	117°38'	65.8	31	05	65.2	59.6	1013	02	6	7	7	1	31	7	33.84	0.34
179	0548	6/12	28°34'	118°18'	64.6	35	07	62.2	57.9	1014	02	6	7	7	1	31	7	33.87	0.39
180	1202	6/12	28°23'	119°04'	64.1	29	09	61.6	56.7	1014	02	6	8	7	1	31	4	33.83	0.37

Table 2.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 52 - con.

Ser. No.	Time, (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp., (°F.)	Wind		Air temp.		Barometer, (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal., (‰)	Surf. PO_4-P, µg.at./1.
						Dir., (°T.)	Force, (kn.)	Dry bulb, (°F.)	Wet bulb, (°F.)			Type	Cover			Dir. (°T.)	Amt.		
181	1642	6/12	28°14'	119°30'	64.1	30	05	63.3	57.2	1016	02	6	7	7	1	31	4	33.89	-
182	1650	6/12	28°14'	119°31'	64.1	30	05	63.3	57.2	1016	02	6	7	7	1	31	4	33.89	-
183	2300	6/12	28°14'	119°34'	65.0	30	07	64.4	58.3	1015	02	6	7	7	1	31	4	-	-
184	0601	6/13	28°04'	120°24'	65.8	33	08	62.8	57.3	1016	03	6	6	7	1	32	1	34.10	0.45
185	1203	6/13	27°51'	121°08'	65.8	33	10	62.1	56.7	1015	02	6	7	7	1	32	1	34.02	0.42
186	1908	6/13	27°38'	121°43'	64.4	00	10	63.8	58.7	1017	02	6	8	7	1	01	1	34.08	0.31
187	0320	6/14	27°33'	122°15'	64.8	36	17	63.3	57.6	1016	02	6,8	7	7	2	34	4	34.12	0.39
188	0326	6/14	27°33'	122°15'	64.8	36	17	63.3	57.6	1016	02	6,8	7	7	2	34	4	34.12	0.39
189	1500	6/14	27°20'	122°16'	65.0	36	16	63.1	58.1	1016	03	6	7	7	2	35	4	-	-
190	1803	6/14	27°30'	122°09'	64.8	01	17	63.6	58.6	1016	01	8	4	7	2	34	3	34.04	0.25
191	1957	6/14	27°42'	122°02'	64.4	35	16	63.4	58.8	1016	02	8	5	7	2	35	3	33.95	0.31
192	0005	6/15	28°03'	121°50'	64.5	01	20	63.9	59.3	1014	01	8	2	7	2	01	3	33.97	0.35
193	0558	6/15	28°30'	121°35'	64.4	01	18	62.6	59.3	1015	03	8	4	7	2	03	3	34.09	0.31
194	1205	6/15	28°53'	121°16'	65.0	01	19	62.2	58.2	1014	02	6,8	4	7	2	02	3	34.03	0.28
195	1802	6/15	29°22'	121°02'	64.2	36	19	62.7	58.0	1016	02	6,8	5	7	2	36	3	33.89	0.29
196	2005	6/15	29°24'	120°54'	64.7	35	20	62.0	57.8	1016	01	6,8	3	7	2	34	3	33.94	0.20
197	0200	6/16	29°42'	120°33'	63.4	35	20	60.8	57.2	1015	02	6,8	4	7	2	36	6	33.57	0.33
198	0603	6/16	30°02'	120°14'	62.1	35	23	60.2	56.8	1014	01	6,8	3	7	3	36	6	33.55	0.43
199	1203	6/16	30°29'	119°40'	61.3	35	22	59.2	55.8	1014	03	6,8	5	7	3	35	6	33.54	0.38
200	1926	6/16	30°48'	119°16'	61.6	34	19	61.0	57.2	1015	01	8	1	7	3	35	6	33.78	0.21
201	2138	6/17	30°46'	119°11'	62.5	34	18	63.0	59.8	1011	02	0	0	7	3	34	7	33.80	0.24
202	2145	6/17	30°46'	119°11'	62.5	34	18	63.0	59.8	1011	02	0	0	7	3	34	7	33.80	0.24
203	1257	6/18	31°11'	119°02'	61.4	32	15	61.7	59.2	1010	02	8	1	7	2	30	1	33.82	0.33
204	1802	6/18	31°30'	118°28'	62.4	31	09	61.2	57.7	1011	03	6	8	7	1	30	1	33.73	2.40
205	2020	6/18	31°38'	118°15'	64.4	27	09	62.7	59.2	1011	02	6	8	7	1	29	1	33.95	0.28
206	0000	6/19	31°50'	117°54'	65.8	27	07	62.6	59.6	1010	02	6	7	7	1	28	1	33.86	0.32
207	0235	6/19	31°59'	117°46'	65.4	33	09	63.2	61.2	1010	01	8,2	4	7	1	28	1	33.72	0.44
208	0240	6/19	31°59'	117°46'	65.4	33	09	63.2	61.2	1010	01	8,2	4	7	1	28	1	33.72	0.44
209	1443	6/19	32°06'	117°38'	64.7	01	06	61.4	58.2	1012	02	6	8	7	1	31	1	-	-
210	1448	6/19	32°06'	117°38'	64.7	01	06	61.4	58.2	1012	02	6	8	7	1	31	1	-	-
211	1800	6/19	32°24'	117°27'	64.8	28	09	63.2	60.7	1012	02	6	8	6	1	29	1	33.78	0.44
212	1858	6/19	32°34'	117°24'	70.9	26	09	65.7	62.4	1012	02	6	8	6	1	29	1	33.86	0.22

Table 3.--Summary of observations at bathythermograph lowerings, N. B. Scofield cruise 59S4

Ser. No.	Time, (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp., (°F.)	Wind		Air temp.		Baro-meter, (mb.)	Wea-ther	Clouds		Visibility	Sea	Swell		Surf. sal., (°/oo)	Surf. PO_4-P, µg.at./1.
						Dir., (°T.)	Force, (kn.)	Dry bulb, (°F.)	Wet bulb, (°F.)			Type	Cover			Dir. (°T.)	Amt.		
1	1835	6/3	34°21'	120°44'	56.2	NW	4	-	-	30.01	-	-	8	7	4	-	-	33.61	0.80
2	1250	6/4	34°33'	121°44'	58.8	NW	6-7	68	-	30.11	-	-	0	8	5	-	-	33.22	0.44
3	1355	6/4	34°35'	121°48'	58.3	NW	6-7	68	-	30.11	-	-	0	8	5	-	-	33.29	1.23
4	1940	6/4	34°47.5'	122°19'	59.0	NW	7-8	65	-	30.03	-	-	1	6	5	-	-	33.06	0.55
5	1235	6/5	34°51'	122°38'	58.8	NW	7	62	-	30.03	-	-	8	6	5	-	-	33.16	0.48
6	2000	6/5	35°12'	123°21'	58.9	NW	6	56	-	30.05	-	-	1	7	4	-	-	-	-
7	1223	6/6	35°23'	124°14'	57.3	NW	6	59	-	30.14	-	-	0	8	5	-	-	32.86	0.96
8	1928	6/6	35°45'	124°52'	59.2	NW	6	56	-	30.10	-	-	1	8	4	-	-	32.44	0.50
9	0602	6/7	36°26'	125°55'	58.0	NW	5-6	57	-	30.14	-	-	3	8	4	-	-	32.81	0.44
10	1114	6/7	35°46'	125°51'	60.2	NW	6	58	-	30.16	-	-	2	8	4	-	-	32.99	0.35
11	1942	6/7	34°50'	126°06'	60.9	NW	4	58	-	30.16	-	-	1	8	4	-	-	32.82	0.51
12	1137	6/8	34°08'	126°26'	60.8	NW	3-4	70.5	-	30.16	-	-	9	4	3	-	-	33.16	0.42
13	1945	6/8	33°10'	126°49'	62.6	NW	4	59	-	30.16	-	-	3	8	4	-	-	33.54	0.31
14	0700	6/9	31°46'	127°18.5'	63.3	NW	4	61	-	30.16	-	-	8	8	4	-	-	33.63	0.32
15	1137	6/9	32°12'	127°43'	63.9	NE	4-5	69	-	30.19	-	-	8	8	4	-	-	33.60	0.28
16	1950	6/9	32°24'	128°04'	63.7	NW	6	59	-	30.19	-	-	7	8	5	-	-	33.25	0.35
17	1131	6/10	33°28'	128°14'	63.7	NW	6	65	-	30.14	-	-	4	8	5	-	-	33.13	0.35
18	1949	6/10	34°19'	128°18'	62.3	NW	5	59	-	30.09	-	-	1	8	5	-	-	33.03	0.38
19	1124	6/11	35°00'	128°52'	61.8	NW	1	64	-	30.08	-	-	2	8	3	-	-	36.52	0.24
20	1904	6/11	35°35'	128°28'	61.2	NW	3	63	-	30.09	-	-	1	8	3	-	-	32.71	0.41
21	1145	6/12	36°12'	128°28'	60.2	NNE	4	67	-	30.07	-	-	2	8	4	-	-	32.87	0.42
22	1951	6/12	36°57'	128°16'	61.0	NNW	5	57	-	30.16	-	-	2	8	4	-	-	32.84	0.42
23	1138	6/13	37°31'	128°10'	60.8	NW	5	66	-	30.20	-	-	1	8	4	-	-	32.64	0.44
24	1950	6/13	36°52'	127°33'	59.2	NW	5	58	-	30.16	-	-	2	8	4	-	-	32.83	0.47
25	1141	6/14	36°19'	127°26'	60.0	NNW	5-6	64	-	30.18	-	-	3	8	4	-	-	32.78	0.44
26	1955	6/14	35°28'	126°40'	61.1	NW	5-6	58	-	30.10	-	-	7	7	4	-	-	32.82	0.45
27	1142	6/15	34°49'	126°04'	60.7	NNW	5	63	-	30.12	-	-	9	7	5	-	-	33.01	0.48
28	1946	6/15	35°28'	126°40'	60.5	NNW	5-6	56	-	30.08	-	-	4	7	5	-	-	33.25	0.42
29	1226	6/16	33°38'	124°58'	60.5	NW	5	64	-	30.11	-	-	4	7	5	-	-	33.31	0.36
30	1945	6/16	33°02'	124°27'	61.3	NW	5+	58	-	30.09	-	-	5	7	5	-	-	33.28	0.38

Table 3.--Summary of observations at bathythermograph lowerings, N. B. Scofield cruise 59S4 - con.

Ser. No.	Time, (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp., (°F.)	Wind		Air temp.		Baro-meter, (mb.)	Wea-ther	Clouds		Visibility	Sea	Swell		Surf. sal., (‰)	Surf. PO_4-P, µg-at./1.
						Dir., (°T.)	Force, (kn.)	Dry bulb, (°F.)	Wet bulb, (°F.)			Type	Cover			Dir. (°T.)	Amt.		
31	1140	6/17	32°25'	123°56'	61.0	NW	5+	64	-	30.05	-	-	1	7	5	-	-	33.25	1.59
32	1940	6/17	32°53'	124°04'	59.8	NW	5+	58	-	29.99	-	-	5	6	5	-	-	32.94	0.50
33	1140	6/18	33°18'	124°09'	59.2	NW	5	65	-	30.02	-	-	9	7-8	5	-	-	33.05	0.44
34	1944	6/18	33°54'	124°21'	60.3	NW	5	59	-	30.00	-	-	9	7-8	5	-	-	33.01	0.48
35	1139	6/19	34°13'	124°22'	60.3	NW	5-6	65	-	30.04	-	-	9	7	5	-	-	32.85	0.39
36	1941	6/19	34°47'	124°36'	60.0	NW	6-7	57	-	30.03	-	-	7	7	5	-	-	32.81	0.41
37	1137	6/20	34°11'	124°40'	60.2	NW	6-7	63	-	30.05	-	-	1	7	6	-	-	32.91	0.42
38	1939	6/20	35°48'	124°24'	58.8	NW	6-7	58	-	29.99	-	-	2	7	6	-	-	32.87	0.46
39	1115	6/21	35°28'	124°05'	59.0	NW	6	59	-	29.96	-	-	1	7	6	-	-	33.04	0.35
40	2002	6/21	34°39'	123°19'	59.4	NW	6	68	-	29.90	-	-	2	7	5	-	-	33.40	0.60
41	1137	6/22	33°48'	123°06'	57.6	NW	5	61	-	29.90	-	-	1	8	4	-	-	33.25	0.47
42	1937	6/22	33°00'	122°52'	60.8	NW	5	58	-	29.80	-	-	1	7	4	-	-	33.36	0.39
43	0535	6/23	32°15'	122°45'	61.1	NW	4-5	59	-	28.80	-	-	1	8	4	-	-	33.30	0.59
44	1137	6/23	32°51'	122°37'	60.7	NW	4-5	63	-	29.92	-	-	1	8	4	-	-	33.45	0.52
45	1925	6/23	33°34'	122°26'	59.2	NW	6	58	-	28.89	-	-	2	7	5	-	-	-	-
46	0920	6/24	32°25'	121°14'	61.8	NW	7	62	-	29.94	-	-	9	7	5	-	-	-	-

Table 4.--Oceanographic observations, Hugh M. Smith cruise 52

Sta. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Salinity (°/oo)	PO_4 (ug.at./1.)	Photometer 50%	Photometer 10%	Photometer 5%	Photometer 1%	Average light (foot candles)	Secchi disk (m.)	Forel color (scale)	Productivity[1]	Zooplankton (g./1,000 m.^{3})	Night-light counts
1	2205	4/29	23°12'	155°27'	35.005	0.34	25.4	61.6	93.4	116.8	-	20.2	1	0.065	-	-
2	0615	4/30	23°51'	154°39'	35.000	-	-	-	-	-	-	-	-	-	74.1	-
3	2200	4/30	25°23'	152°43'	34.760	0.81	20.5	58.0	89.0	127.0	-	27.4	1	0.133 0.195	-	-
4	0605	5/1	26°12'	151°48'	34.974	-	-	-	-	-	-	-	-	-	66.5	-
5	2205	5/1	27°49'	149°47'	35.153	0.49	2.5	48.0	79.0	134.5	-	27.4	1	0.065	-	-
6	0605	5/2	28°40'	148°47'	35.110	-	-	-	-	-	-	-	-	-	29.4	-
7	2210	5/2	30°21'	146°41'	34.974	0.32	-	-	-	-	-	27.4	1	0.219	-	-
8	0537	5/3	31°06'	145°41'	34.610	-	-	-	-	-	-	-	-		54.7	-
9	2100	5/3	32°37'	143°43'	34.427	0.20	7.5	41.0	77.5	137.0	-	27.4	1	-0.049 0.121	-	-
10	0532	5/4	33°16'	142°49'	34.117	-	-	-	-	-	-	-	-	-	16.7	-
11	2100	5/4	34°23'	141°13'	34.063	1.65	26.0	50.0	83.1	128.3	6750	25.6	1	0.007	-	-
12	0301	5/5	34°48'	140°41'	34.041	0.20	-	-	-	-	-	-	-	0.149	-	1 squid
13	2100	5/5	35°17'	140°13'	33.902	0.33	-	73.2	93.5	130.6	7500	27.4	1	0.058	-	-
14	0530	5/6	35°53'	139°14'	33.753	-	-	-	-	-	-	-	-	-	33.7	-
15	1657	5/6	36°48'	138°00'	33.726	0.42	45.0	76.2	81.8	115.0	7500	31.0	1	0.089 0.022	-	-
16	0530	5/7	37°12'	137°31'	35.665	-	-	-	-	-	-	-	-	-	33.0	-
17	2100	5/7	38°28'	135°50'	33.171	0.44	11.0	42.8	65.5	128.7	4050	23.8	1	0.053	-	-
18	0301	5/7	38°48'	135°06'	33.214	0.55	-	-	-	-	-	-	-	-	-	30-100 saury, a few squid
18	1630	5/8	38°48'	135°06'	-	-	-	24.8	58.3	105.0	2000	20.2	1	0.042	-	-
19	2100	5/8	38°28'	134°39'	33.118	0.36	-	53.6	70.4	100.4	4400	21.9	1	-	-	-
20	0530	5/9	37°47'	133°46'	-	-	-	-	-	-	-	-	-	-	103.0	-
21	2100	5/9	36°40'	132°21'	33.616	0.51	5.6	44.9	75.4	129.9	2923	21.9	1	0.062	-	-
22	0307	5/10	36°39'	132°24'	-	0.34	-	-	-	-	-	-	-	-	-	30-100 saury, 1 squid
22	1615	5/10	36°39'	132°24'	-	-	-	46.3	73.1	121.5	1815	21.9	1	-	-	-
22a	2000	5/10	36°21'	131°51'	-	-	-	-	-	-	-	-	-	0.079	-	-
23	0505	5/11	35°38'	131°05'	33.216	-	-	-	-	-	-	-	-	-	25.9	-
24	2000	5/11	34°32'	129°32'	33.200	0.51	-	31.9	53.4	94.7	7000	29.3	1	0.112 0.033	-	-
25	0431	5/12	33°54'	128°45'	33.193	-	-	-	-	-	-	-	-	-	33.7	-
25a	2000	5/12	34°36'	126°54'	-	-	-	-	-	-	-	-	-	0.066	-	-
25b	1900	5/13	37°24'	123°02'	-	-	-	-	-	-	-	-	-	1.854	-	-
26	1600	5/17	33°19'	128°00'	33.278	0.45	23.6	29.0	66.4	104.7	7500	27.4	1	0.108 0.063	-	-
27	0430	5/17	32°04'	127°24'	-	-	-	-	-	-	-	-	-	-	10.3	-
28	2000	5/18	31°26'	125°32'	33.693	0.22	-	54.6	83.2	118.2	8400	31.1	1	0.017	-	-
29	0430	5/19	30°48'	125°52'	-	-	-	-	-	-	-	-	-	-	18.4	-
29a	2000	5/19	29°25'	124°02'	-	-	-	-	-	-	-	-	-	0.119 0.047	-	-
29b	2000	5/20	29°39'	123°56'	-	-	-	-	-	-	-	-	-	0.067	-	-
30	1600	5/21	28°53'	123°24'	34.099	0.32	2.0	41.3	74.3	125.5	4283	25.6	1	0.097	-	-

---

[1] Productivity values are in milligrams of carbon converted from inorganic to organic carbon per hour per meter of water. Where two values of productivity are given the replicate light bottle values differed by more than 20 percent of the lower value. Negative numbers mean essentially no productivity measured, as do other numbers in the third decimal place.

Table 4.--Oceanographic observations, Hugh M. Smith cruise 52 - con.

Sta. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Salinity (°/oo)	PO_4 (ug.at./1.)	Photometer				Average light (foot candles)	Secchi disk (m.)	Forel color (scale)	Productivity[1/]	Zooplankton (g./1,000 m.^{3})	Night-light counts
							50%	10%	5%	1%						
31	0427	5/22	28°27'	123°04'	-	-	-	-	-	-	-	-	-	-	18.7	-
32	1600	5/22	27°21'	122°07'	34.281	0.26	5.0	42.8	78.9	130.9	7300	23.8	1	0.063	-	-
33	0200	5/23	26°59'	121°59'	34.155	0.28	-	-	-	-	-	-	-	-0.033 -0.010	-	1-5
33	1600	5/23	26°59'	121°59'	-	-	8.9	22.0	78.8	129.0	4312	27.4	1	-	-	-
34	2030	5/23	26°51'	121°32'	34.060	0.26	13.4	55.8	81.7	129.2	7550	32.9	1	0.166	-	-
35	0205	5/24	27°00'	120°56'	33.974	0.27	-	-	-	-	-	-	-	-	-	1-5 unid. sm. fish, 7 squid
36	2000	5/24	27°00'	120°18'	34.060	0.26	12.0	47.7	75.2	126.4	4500	25.6	1	0.057 0.121	-	-
37	0202	5/25	27°00'	119°31'	33.974	0.29	-	-	-	-	-	-	-	-	-	30-100 saury
38	2000	5/25	27°04'	118°53'	34.050	0.27	0.5	47.0	64.8	110.4	7050	27.4	1	0.076	-	-
39	0400	5/26	27°33'	118°23'	-	-	-	-	-	-	-	-	-	-	16.6	-
40	2000	5/26	29°52'	117°58'	33.609	0.32	3.1	36.7	63.4	112.7	2715	18.3	1	0.095	-	-
41	0400	5/27	30°56'	117°47'	-	-	-	-	-	-	-	-	-	-	73.4	-
42	1830	5/29	San Diego	harbor	-	-	-	-	-	-	-	-	-	-	-	-
43	2000	5/30	32°30'	117°46'	33.703	0.32	10.5	27.8	38.9	49.2	7950	18.3	2	0.228	-	-
44	0205	5/31	32°30'	118°20'	33.673	0.34	-	-	-	-	-	-	-	-	-	About 1000 small anchovie
44a	1515	5/31	32°33'	118°26'	33.693	0.37	-	-	-	-	-	-	-	0.694	-	-
45	2000	5/31	32°33'	119°07'	33.579	0.48	2.0	14.5	29.0	75.4	3450	14.6	4	0.887	-	-
46	0200	6/1	32°08'	119°35'	33.480	-	-	-	-	-	-	-	-	-	-	Nothing under light
46a	1515	6/1	32°05'	119°28'	-	0.86	-	-	-	-	-	-	-	0.166 0.065	-	-
47	2000	6/1	32°04'	120°05'	33.464	0.41	1.1	24.1	41.6	83.0	2760	16.4	2	0.338	-	-
48	0431	6/2	32°07'	121°19'	-	-	-	-	-	-	-	-	-	-	67.5	-
49	2000	6/2	31°49'	123°34'	33.543	0.37	2.4	37.0	71.9	124.4	3360	23.7	1	0.044	-	-
50	0432	6/3	31°08'	124°22'	-	-	-	-	-	-	-	-	-	-	23.0	-
51	2000	6/3	31°03'	124°54'	33.586	0.38	16.1	53.7	80.6	123.5	8100	34.7	1	0.063	-	-
52	0430	6/4	31°27'	124°56'	-	-	-	-	-	-	-	-	-	-	39.1	-
53	2000	6/4	30°39'	124°18'	33.475	0.46	5.2	23.7	76.5	125.5	6000	31.2	1	0.035 0.075	-	-
54	0201	6/5	30°28'	123°35'	33.537	0.37	-	-	-	-	-	-	-	-	-	Nothing under light
55	2000	6/5	30°20'	123°05'	33.693	0.35	6.0	43.2	70.9	101.8	3450	27.4	1	0.072	-	-
56	0430	6/6	30°11'	122°07'	-	-	-	-	-	-	-	-	-	-	10.3	-
57	2000	6/6	29°59'	120°57'	33.548	0.39	-	48.8	67.6	-	7440	25.6	1	0.043	-	-
58	0430	6/7	29°51'	120°27'	-	-	-	-	-	-	-	-	-	-	13.1	-
59	1958	6/7	29°48'	118°37'	33.486	0.36	-	-	-	-	-	-	-	0.083 0.176	-	-
60	1644	6/8	29°28'	117°55'	33.811	0.31	-	-	-	-	-	-	-	0.099	-	-

Table 4.--Oceanographic observations, Hugh M. Smith cruise 52 - con.

Sta. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Salinity ($^{o}/oo$)	PO_4 (ug.at./1.)	Photometer				Average light (foot candles)	Secchi disk (m.)	Forel color (scale)	Productivity[1]	Zooplankton (g./1,000 $m.^3$)	Night-light counts
							50%	10%	5%	1%						
61	0430	6/9	29°09'	117°53'	-	-	-	-	-	-	-	-	-	-	11.5	-
62	2000	6/9	28°57'	118°01'	33.842	0.35	4.0	46.3	62.1	90.6	8400	29.3	1	0.079	-	-
63	0245	6/10	28°50'	117°57'	33.805	0.33	-	-	-	-	-	-	-	-	-	Nothing under light
64	2000	6/10	28°09'	117°18'	33.832	0.94	1.2	40.5	61.2	107.5	3300	23.8	1	0.006	-	-
65	0205	6/11	29°23'	117°00'	33.690	0.42	-	-	-	-	-	-	-	-	-	Occasional saury, 1 Myctophid
66	2000	6/11	28°57'	117°15'	33.726	0.49	7.7	38.4	71.1	113.6	5070	29.3	1	0.017	-	-
67	0403	6/12	28°37'	118°07'	-	-	-	-	-	-	-	-	-	-	-	-
68	2000	6/12	28°14'	119°31'	33.891	-	7.2	34.8	63.0	112.0	4520	-	-	0.096	-	-
69	0428	6/13	28°04'	120°08'	-	-	-	-	-	-	-	-	-	-	12.6	-
70	1915	6/13	27°33'	121°45'	34.085	0.31	5.1	45.9	79.2	130.0	3000	31.2	1	-0.091	-	-
71	0210	6/14	27°33'	122°15'	33.117	0.39	-	-	-	-	-	-	-	-	-	Nothing under light
72	2000	6/14	27°42'	122°00'	33.954	0.31	5.7	54.0	81.6	100.3	2780	34.7	1	-0.073 -0.098	-	-
73	0430	6/15	28°23'	121°39'	-	-	-	-	-	-	-	-	-	-	12.7	-
74	2005	6/15	29°55'	120°20'	33.938	0.29	-	-	-	-	-	-	-	-0.068 -0.174	-	-
75	0435	6/16	29°55'	120°20'	-	-	-	-	-	-	-	-	-	-	17.6	-
76	1926	6/16	30°48'	119°16'	33.775	0.21	-	-	-	-	-	-	-	0.555 0.112	-	-
77	2138	6/17	30°47'	119°10'	33.798	0.24	-	-	-	-	-	-	-	0.291 0.154	-	-
78	0430	6/18	31°20'	119°14'	-	-	-	-	-	-	-	-	-	-	48.9	-
79	2000	6/18	31°38'	118°15'	33.950	0.28	4.5	17.2	29.0	63.0	4620	16.4	4	0.871	-	100-500 sm. unid. fish
80	0203	6/19	31°59'	117°46'	33.722	0.44	-	-	-	-	-	-	-	0.822	-	-

Table 5.--Oceanographic observations, N. B. Scofield cruise 59S4

Sta. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Salinity (°/oo)	PO_4 (ug.at./l.)	Productivity[1]	Plankton (g./1,000 $m.^3$)
1	0235	6/4	34°21'	120°41'	33.61	0.80	-	-
1	0305	6/4	34°21'	120°41'	-	-	-	23.3
2	2050	6/4	34°35'	121°44'	33.22	0.44	-	-
3	2155	6/4	34°47'	122°19'	33.29	1.23	-	-
4	0340	6/5	34°53'	122°40'	33.06	0.55	-	-
5	2035	6/5	35°12'	123°21'	33.16	0.48	-	-
6	0400	6/6	35°23'	124°14'	-	0.65	-	-
7	1223	6/6	35°45'	124°52'	32.86	0.96	-	-
8	0328	6/7	36°25'	125°55'	32.44	0.50	-	-
9	1402	6/7	35°46'	125°59'	32.81	0.44	-	-
10	1914	6/7	34°50'	126°06'	32.99	0.35	-	-
10	1930	6/7	34°50'	126°06'	-	-	0.078	34.9
11	0342	6/8	34°06'	126°27'	32.82	0.51	-	-
11	0403	6/8	34°06'	126°27'	-	-	-	-
12	1937	6/8	33°10'	126°48'	33.16	0.42	-	-
12	1947	6/8	33°10'	126°49'	-	-	0.082	56.3
13	0345	6/9	31°46'	127°18'	33.54	0.31	-	-
13	0358	6/9	31°46'	127°18'	-	-	-	-
14	1500	6/9	32°12'	127°43'	33.63	0.32	-	-
15	1937	6/9	32°24'	128°04'	33.60	0.28	-	-
15	1951	6/9	32°24'	128°04'	-	-	0.150 0.086	-
16	0350	6/10	32°28'	128°14'	33.25	0.35	-	-
17	1931	6/10	34°19'	128°18'	33.13	0.35	-	-
17	1945	6/10	34°19'	128°18'	-	-	0.095 0.138	-
18[2]	0349	6/11	35°02'	128°27'	33.03	0.38	-	-
19	1924	6/11	35°35'	128°27'	36.52	0.24	-	-
19	1942	6/11	35°35'	128°27'	-	-	0.114	-
20	0304	6/12	36°12'	128°28'	32.71	0.41	-	-
21	1945	6/12	36°57'	128°16'	32.87	0.42	-	-
21	1958	6/12	36°57'	128°16'	-	-	0.212	-
22	0350	6/13	37°29'	128°16'	-	-	-	-
22	0351	6/13	37°29'	128°16'	32.84	0.42	-	-
22	1938	6/13	37°29'	128°16'	-	-	0.019	-
22	1950	6/13	37°29'	128°18'	-	-	0.051	-
23	0350	6/14	36°52'	127°33'	32.64	0.44	-	-
23	0400	6/14	36°52'	127°35'	-	-	-	57.1
24	1941	6/14	36°19'	127°26'	32.83	0.47	-	-
24	1955	6/14	36°19'	127°26'	-	-	0.124 0.236	-
25	0355	6/15	35°28'	126°40'	32.78	0.44	-	-
26	1942	6/15	34°49'	126°04'	33.82	0.45	-	-
26	1955	6/15	34°49'	126°04'	-	-	0.201	-
27	0346	6/16	34°09'	125°32'	33.01	0.48	-	-
28	2026	6/16	33°38'	124°58'	33.25	0.42	-	-
29	0345	6/17	33°02'	124°27'	33.31	0.36	-	-
30	1940	6/17	32°25'	123°56'	33.28	0.38	-	-
30	1954	6/17	32°25'	123°56'	-	-	0.107	-

---

[1] Productivity values are in milligrams of carbon converted from inorganic to organic carbon per hour per meter or water. Where two values of productivity are given the replicate light bottle values differed by more than 20 percent of the lower value. Negative numbers mean essentially no productivity measured, as do other numbers in the third decimal place.

[2] Miscellaneous data - One Secchi disc reading was taken at Station 18 (31 meters).

Table 5.--Oceanographic observations, N. B. Scofield cruise 59S4 - con.

Sta. No.	Time (GCT)	Date 1959	Latitude N.	Longitude W.	Salinity (°/oo)	PO_4 (ug.at./l.)	Productivity[1]/	Plankton (g./1,000 m.[3])
31	0340	6/18	32°53'	124°04'	33.25	1.59	-	-
32	1940	6/18	33°18'	124°09'	32.94	0.50	-	-
32	1950	6/18	33°18'	124°09'	-	-	0.078 0.267	-
33	0344	6/19	33°53'	124°21'	33.05	0.44	-	-
34	1939	6/19	34°13'	124°22'	33.01	0.48	-	-
34	1952	6/19	34°13'	124°22'	-	-	0.083 0.132	-
35	0341	6/20	34°47'	124°36'	32.85	0.39	-	-
36	1937	6/20	35°11'	124°40'	32.81	0.41	-	-
36	1955	6/20	35°11'	124°40'	-	-	-0.005 0.065	-
37	0339	6/21	35°48'	124°24'	32.91	0.42	-	-
38	1915	6/21	35°28'	124°05'	32.87	0.46	-	-
38	1926	6/21	35°28'	124°05'	-	-	0.472	-
39	0402	6/22	34°39'	123°19'	33.04	0.35	-	-
40	1937	6/22	33°48'	123°06'	33.40	0.60	-	-
40	1949	6/22	33°48'	123°06'	-	-	2.221 3.665	-
41	0337	6/23	33°00'	122°52'	33.25	0.47	-	-
41	0349	6/23	33°00'	122°52'	-	-	-	601.9
42	1335	6/23	32°15'	122°45'	33.36	0.39	-	-
43	1937	6/23	32°51'	122°37'	33.30	0.59	-	-
43	1949	6/23	32°51'	122°37'	-	-	-	-
44	0325	6/24	33°34'	121°26'	33.45	0.52	-	-
45	1720	6/24	32°25'	121°14'	-	0.38	-	-

Table 6.--Sightings of tuna schools, birds, and aquatic mammals, Hugh M. Smith cruise 52

Date, 1959	Noon position		Flocks				Scattered birds									Tuna schools	Aquatic mammals		
			Number of birds			Species comprised													
	Latitude N.	Longitude W.	<10	11-50	>50	Petrel or shearwater	Tern	Tropic-bird	Frigate bird	Petrel or shearwater	Storm petrel	Albatross	Bos'un bird	Sea gull	Snipe		Porpoise	Whale	Seal
4/29	23°13'	155°28'	-	-	-	-	5	1	2	36	7	1	1	-	-	-	-	-	-
4/30	25°23'	152°43'	-	-	-	-	10	3	-	16	10	7	1	-	-	-	-	-	-
5/1	27°49'	149°47'	-	-	-	-	10	4	-	17	21	14	-	-	-	-	-	-	-
5/2	30°21'	146°42'	-	-	-	-	-	2	-	5	6	12	-	-	-	-	-	-	-
5/3	32°37'	143°44'	-	-	-	-	-	-	-	1	17	3	-	-	-	-	-	-	-
5/4	34°23'	141°14'	-	-	-	-	-	-	-	9	4	6	-	-	-	-	-	-	-
5/5	35°17'	140°13'	-	-	-	-	-	-	-	4	9	2	-	-	-	-	15	12	-
5/6	36°49'	138°00'	-	-	-	-	-	2	-	3	2	6	-	-	-	-	-	-	-
5/7	38°28'	135°51'	-	-	-	-	-	-	-	9	16	6	-	-	-	-	100	-	-
5/8	38°28'	134°39'	-	-	-	-	-	-	-	20	19	9	-	-	-	-	-	-	-
5/9	36°40'	132°21'	-	-	-	-	-	3	-	17	14	7	1	-	-	-	20	-	-
5/10	36°18'	131°49'	-	-	-	-	-	-	-	5	3	15	-	-	-	-	-	-	-
5/11	34°33'	129°32'	-	-	-	-	-	-	-	10	6	24	-	-	-	-	-	-	-
5/12	34°37'	126°55'	-	-	-	-	-	-	-	41	13	5	-	-	55	-	-	-	1
5/13	37°24'	123°03'	-	-	1	800	-	-	-	61	-	2	-	8	18	-	20	-	37
5/15	37°24'	123°13'	-	-	-	-	2	-	-	64	1	1	20	18	-	-	-	2	-
5/16	35°45'	126°03'	-	-	-	-	9	-	-	27	5	12	-	-	-	-	-	2	-
5/17	33°20'	127°58'	-	-	-	-	-	-	-	5	7	15	-	-	-	-	-	-	-
5/18	31°27'	125°33'	-	-	-	-	-	-	-	3	5	23	-	-	-	-	-	-	-
5/19	29°25'	124°03'	-	-	-	-	-	-	-	21	7	10	-	-	-	-	-	-	-
5/20	29°39'	123°56'	-	-	-	-	-	1	-	9	5	4	-	-	-	-	-	-	-
5/21	28°53'	123°24'	-	-	-	-	-	-	-	31	14	6	-	-	-	-	-	-	-
5/22	27°21'	122°08'	-	-	-	-	-	1	-	-	-	3	-	-	-	-	-	-	-
5/23	26°52'	121°35'	-	-	-	-	1	2	-	9	1	1	-	1	-	-	-	-	-
5/24	27°00'	120°19'	-	-	-	-	-	2	-	22	11	-	-	-	-	-	-	-	-
5/25	27°04'	118°53'	-	-	-	-	-	-	-	66	8	-	-	-	-	-	-	-	-
5/26	29°52'	117°59'	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-
5/27	San Diego harbor																		
5/30	32°31'	117°46'	-	1	-	30	13	-	-	18	44	3	-	74	-	-	15	-	-
5/31	32°33'	119°07'	-	-	-	-	18	-	-	58	53	10	-	-	-	-	15	1	-
6/1	32°04'	120°05'	-	-	-	-	-	-	-	-	2	67	1	-	-	-	-	-	-
6/2	31°50'	123°34'	-	-	-	-	-	-	-	3	27	3	-	-	-	-	-	-	-
6/3	31°04'	124°54'	-	-	-	-	2	-	-	2	-	2	-	-	-	-	-	-	-
6/4	30°39'	124°18'	-	-	-	-	-	1	-	9	11	2	-	-	-	-	-	-	-
6/5	30°20'	123°05'	-	-	-	-	-	-	-	9	-	1	-	-	-	-	-	-	-
6/6	29°60'	120°58'	-	-	-	-	-	-	-	9	6	1	-	-	-	-	-	-	-
6/7	29°42'	118°37'	-	1	-	30	-	1	-	19	19	4	-	-	-	1	-	-	-
6/8	29°38'	117°55'	-	-	-	-	-	-	-	27	47	1	-	-	-	-	-	-	-
6/9	28°57'	118°01'	-	-	-	-	-	-	-	60	21	1	-	23	-	-	-	2	-
6/10	29°10'	117°18'	1	1	-	13 10	-	-	-	33	73	-	-	1	-	-	1000	3	
6/11	28°57'	117°15'	-	-	1	500	-	-	-	43	41	2	-	1	-	-	1100+	12	-
6/12	28°14'	119°31'	-	-	-	-	-	-	-	14	45	1	-	1	-	-	-	-	-
6/13	27°34'	121°45'	-	1	-	20	-	-	-	5	2	14	-	-	-	-	-	-	-
6/14	27°43'	122°00'	-	-	-	-	-	-	-	51	13	4	-	-	-	-	-	-	-
6/15	29°24'	120°54'	-	-	-	-	-	-	-	8	8	4	-	-	-	-	-	-	-
6/16	30°48'	119°13'	-	-	-	-	-	-	-	11	22	4	-	-	-	-	-	-	-
6/17	30°45'	119°11'	-	-	-	-	-	-	-	3	29	7	-	-	-	-	-	-	-
6/18	31°38'	118°15'	-	-	-	-	-	-	-	15	42	8	-	1	-	-	60+	2	-
6/19	32°34'	117°25'	-	-	1	120	7	-	-	18	4	18	-	16	-	-	-	-	-

Table 7.--Sightings of birds and aquatic mammals, N. B. Scofield cruise 59S4

Date, 1959	Sighted within		Observations
	Latitude N.	Longitude W.	
6/4	34°48' 34°53'	122°19' 122°40'	terns, storm petrels, shearwaters abundant. 1 albatross
6/5	35°12' 35°23'	123°21' 124°12'	no birds or mammals sighted
6/6	35°23'	124°14'	1-6 albatross
6/7	35°46' 34°50'	125°59' 126°06'	1-6 albatross
6/8	34°06' 33°10'	126°27' 126°49'	1-6 albatross
6/9	31°46' 32°24'	127°19' 128°04'	1-6 albatross
6/10	34°19'	128°18'	1-6 albatross
6/11	35°35'	128°28'	1-6 albatross, several whales
6/12	36°57'	128°16'	1-6 albatross, 1 storm petrel
6/13	36°52'	127°33'	several storm petrels
6/14	35°28'	126°40'	several Beal's petrels
6/15	34°09'	125°32'	no birds or mammals sighted
6/16	33°02'	124°27'	1-6 albatross
6/17	32°53'	124°04'	1-6 albatross
6/18	33°54'	124°21'	1-6 albatross
6/19	34°47'	124°36'	3 albatross
6/21	35°48'	124°24'	1-6 albatross, 2 whales
6/22	34°39'	123°19'	scattered Beal's petrels, 6 albatross
6/23	33°00'	122°52'	1-6 albatross
6/24	33°34' 32°25'	122°26' 121°14'	2 albatross

DISPLAY COPY

CALANOID COPEPODS FROM EQUATORIAL WATERS OF THE PACIFIC OCEAN

By GEORGE D. GRICE

FISHERY BULLETIN 186
From Fishery Bulletin of the Fish and Wildlife Service
VOLUME 61

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES

UNITED STATES DEPARTMENT OF THE INTERIOR, Stewart L. Udall, *Secretary*
FISH AND WILDLIFE SERVICE, Clarence F. Pautzke, *Commissioner*
BUREAU OF COMMERCIAL FISHERIES, Donald L. McKernan, *Director*

CALANOID COPEPODS FROM EQUATORIAL WATERS OF THE PACIFIC OCEAN

By GEORGE D. GRICE

March 3, 1849

FISHERY BULLETIN 186
From Fishery Bulletin of the Fish and Wildlife Service
VOLUME 61

[Contribution No. 1072, Woods Hole Oceanographic Institution]
Published by the U.S. Fish and Wildlife Service • 1961
Printed at the U.S. Government Printing Office, Washington

For sale by the Superintendent of Documents, U.S. Government Printing Office,
Washington 25, D.C.—Price 45 cents

Library of Congress catalog card for the series, Fishery Bulletin of the Fish and Wildlife Service:

U. S. *Fish and Wildlife Service.*
Fishery bulletin. v. 1–
Washington, U. S. Govt. Print. Off., 1881–19

v. in illus., maps (part fold.) 23–28 cm.

Some vols. issued in the congressional series as Senate or House documents.
Bulletins composing v. 47– also numbered 1–
Title varies: v. 1–49, Bulletin.
Vols. 1–49 issued by Bureau of Fisheries (called Fish Commission, v. 1–23)

1. Fisheries—U.S. 2. Fish-culture—U.S. I. Title.

SH11.A25 639.206173 9—35239*

Library of Congress [59r55b1]

CONTENTS

Page
Materials ---------- 172
Methods ---------- 172
General remarks ---------- 174
Taxonomy ---------- 175
Family:
Calanidae ---------- 175
Eucalanidae ---------- 180
Paracalanidae ---------- 183
Pseudocalanidae ---------- 189
Aetideidae ---------- 190
Euchaetidae ---------- 199
Phaennidae ---------- 203
Scolecithricidae ---------- 206
Temoridae ---------- 213
Metridiidae ---------- 215
Centropagidae ---------- 218
Lucicutiidae ---------- 220
Heterorhabdidae ---------- 222
Augaptilidae ---------- 223
Arietellidae ---------- 226
Candaciidae ---------- 228
Pontellidae ---------- 239
Acartiidae ---------- 240
Literature cited ---------- 241

ABSTRACT

A systematic study was made of the calanoid copepods found in 14 zooplankton samples, four of which were obtained from within the recently discovered equatorial undercurrent (Cromwell current), collected between 5° N. and 5° S. and 130° E. and 120° W.

One hundred and ten species belonging to 18 families were recorded. Descriptive notes, measurements and figures were given for most species with citations to previous occurrences in the Pacific Ocean.

Except for *Scolecithricella tenuiserrata* (Giesbrecht), the copepod species in samples collected from within the equatorial undercurrent were not very different from those in samples obtained adjacent to the current. The numerical abundance and species diversity in equatorial waters were briefly compared with that reported for the northwestern Pacific Ocean. *Acrocalanus andersoni* Bowman, *Chirundina indica* Sewell and *Haloptilus fertilis* (Giesbrecht) were reported for the first time from the Pacific Ocean.

Three species, *Xanthocalanus dilatus*, *Amallophora smithae* and *Scolecithricella tropica*, are described as new, and hitherto unknown males of *Gaetanus miles* Giesbrecht and *G. minor* Farran are briefly illustrated from juvenile specimens. It was proposed that *Euchirella brevis* Sars is a synonym for *E. amoena* Giesbrecht; *Euchaeta consimilis* Farran for *E. concinna* Dana; *Scoecithrix longicornis* Scott, and *Scolecithricella spinipedata* Mori for *Scolecithricella ctenopus* (Giesbrecht); and *Centropages pacificus* Chiba for *C. elongatus* Giesbrecht.

CALANOID COPEPODS FROM EQUATORIAL WATERS OF THE PACIFIC OCEAN

By GEORGE D. GRICE, *Woods Hole Oceanographic Institution* [1]

The present paper concerns the calanoid pepods found in plankton samples collected ong the equator, an area which has been relavely unexplored taxonomically.

Systematic studies on calanoid copepods have ade these microcrustaceans one of the better nown groups of the holoplankton of the Pafic Ocean. Extensive taxonomic reports are ailable for the north Pacific (Brodsky, 1950), e northeast Pacific (Davis, 1949), the westn Pacific (Vervoort, 1946; Tanaka, 1953), d the Pacific sector of the Antarctic (Verort, 1957). In addition there are numerous naller but nevertheless valuable papers conrning the calanoid copepods of more restricted areas. Although there remain large, unexplored areas, these recent papers and certain of the older ones (e.g., Scott, 1909) provide a framework for a zoogeographic study of Pacific calanoids and, moreover, show where additional investigations are needed.

Most of the laboratory work of this study was done in Honolulu, Hawaii, in 1958 and 1959 under a fellowship from the John Simon Guggenheim Memorial Foundation. I wish to express my appreciation to the Foundation for the opportunity to make this study. The U.S. Fish and Wildlife Biological Laboratory furnished space for the work, the use of their library facilities and a part of their extensive plankton collections. It is a pleasure to acknowledge the cooperation of Thomas S. Aus-

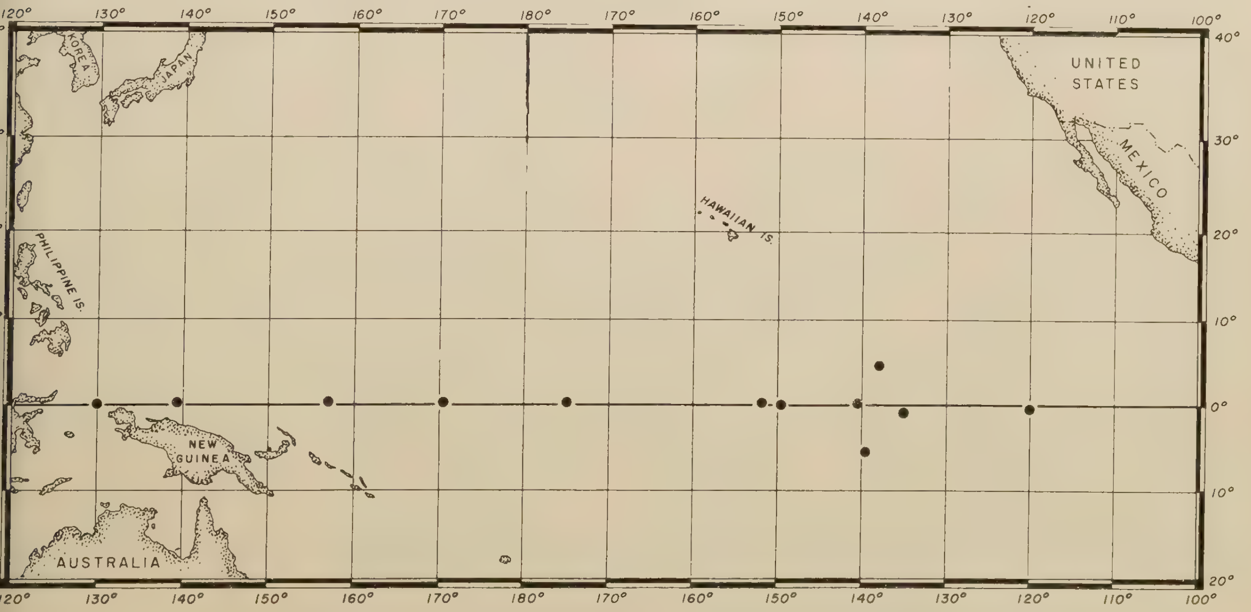


FIGURE 1. Positions where plankton samples were obtained.

Woods Hole, Mass.

Fishery Bulletin 186. Approved for publication July 21, 1960.

tin and E. C. Jones. I wish also to thank Dr. Paul Illg for his advice during the course of the work, Dr. Thomas E. Bowman for reviewing the manuscript, and my wife, Joan, for assistance in completing the drawings.

MATERIALS

The present report is based on the examination of 14 plankton samples collected between 5° N. and 5° S. latitude and between 130° E. and 120° W. longitude in the Pacific Ocean (fig. 1). The pertinent data associated with each plankton collection are presented in table 1. Hydrographic data associated with these collections are given by King, Austin, and Doty (1957) for the research vessel *Hugh M. Smith*, cruise 31, and by Austin (1957) for cruise 35. Processed reports containing hydrographic data have been issued for *Orsom* cruise 56–4 (Legand, 1957), for *Stranger* and *Horizon* cruises (Scripps Institution of Oceanography, 1957), and for *Satsuma* and *Kagoshima* cruises (Japanese Hydrographic Office, 1956).

Four of the 14 samples (*Smith* cruise 31, stations 94, 144, 178, and cruise 47, station 31) were obtained from the recently discovered equatorial undercurrent (Knauss and King, 1958) by means of closing net gear. In addition, one oblique tow (*Smith* cruise 35, station 63) apparently passed within the undercurren at least during part of the tow.

The three samples obtained on cruise 47 wer oriented with respect to the undercurrent. On sample (cruise 47, station 31) was collecte within the current, and the other two were obtained from below it (cruise 47, station 29 and from above it (cruise 47, station 30).

Six collections (*Smith* cruise 35, station 63 *Stranger* 34, *Orsom* 10, *Horizon* 32, *Satsum* 32, and *Kagoshima* 613) were selected from large number of plankton samples obtained b vessels participating in a large scale quasi-synoptic study (Operation Equapac) in Pacifi equatorial waters. The samples used in th present studies are those obtained nearest t the Equator by each of the vessels.

METHODS

Owing to the large volume of most of th samples, except *Kagoshima* 613, it was no practical to examine the entire contents of each In order to estimate the percentage representation and the numerical abundance of th common species, small quantities of the original samples were examined. These sub-samples, the sizes of which are given in table 2 were obtained by means of a plankton splitte (McEwen, Johnson, and Folsom, 1954). O

TABLE 1.—*Plankton station data*

Research vessel	Agency	Cruise No.	Station No.	Position	Date	Time[1]	Size of net	Mesh (mm.)	Depth [2] (m.)	Wate filtere (m.³)
Hugh M. Smith	U.S. Fish and Wildlife Service.	31	94–2	00°11′S 119°58′W	*1955* Nov. 7	0916–0946 ZT	1 m.	0.65	146–72 CN	590.
Do	do	31	132–2	04°40′N 138°14′W	Nov. 17	0921–0950 ZT	1 m.	.65	119–63 CN	690.
Do	do	31	144–2	00°16′N 140°12′W	Nov. 20	1000–1036 ZT	1 m.	.65	122–61 CN	38.
Do	do	31	153–3	05°31′S 139°54′W	Nov. 22	1008–1039 ZT	1 m.	.65	126–63 CN	966.
Do	do	31	178–2	00°21′N 151°40′W	Dec. 6	0917–0947 ZT	1 m.	.65	146–68 CN	283.
Do	do	47	30	00°00′ 149°36′W	*1958* Oct. 27	1118–1151 ZT	1 m.	.65	surface	1342.
Do	do	47	31	00°00′ 149°33′W	do	1153–1246 ZT	1 m.	.65	100 CN	380.
Do	do	47	29	00°00′ 149°38′W	do	0953–1112 ZT	1 m.	.65	500 CN	922.
Do	do	35	63–1	01°10′S 134°57′W	*1956* Aug. 19	2116–2152 ZT	1 m.	.66	169 Q	
Stranger	Scripps Institution of Oceanography.		34	00°01′N 174°59′W	Sept. 15	0352 GMT	1 m.	.56	0–140 Q	
Orsom	Institut Français d'Océanie.	56–4	10	00°35′N 170°11′E	Oct. 4	2338–2457 LT	50 cm.	.366	150 Q( )	616.
Horizon	Scripps Institution of Oceanography.		32	00°03′S 157°00′E	Aug. 25	0428 GMT	1 m.	.56	0–280 Q	
Satsuma	Japan Hydrographic Office.		32	00°29′N 139°49′E	Aug. 18	2100–2210 ZT	45 cm.	.33	0–150 Q	20.
Kagoshima-Maru	Kagoshima University, Japan.		613	00°38′N 130°20′E	Aug. 1	0725–0955 ZT	22.5 cm.	.11	0–50 V	

[1] ZT, zone time; LT, local time; GMT, Greenwich mean time.
[2] CN, closing net; Q, oblique open net; V, vertical open net.

TABLE 2.—*List of species and number of specimens in each sub-sample*

["X" indicates the species was found during the examination of other fractions of original sample]

Species	*Hugh M. Smith*									*Stranger*	*Orsom*	*Horizon*	*Satsuma*	*Kagoshima*
	94	132	144	153	178	30	31	29	63	34	10	32	32	613
1. Calanus tenuicornis	2	1		3	2							1		
2. Nannocalanus minor	1	44	2	21	41		2	X	2	6	6	12		
3. Canthocalanus pauper									1	1		2		
4. Neocalanus gracilis	X	8		6			17			X	X		X	
5. N. robustior				1	X				1	X				
6. Undinula vulgaris													X	
7. U. darwini	1	1	4	72	57	20	11	X	39	6	2	11	6	
8. Eucalanus attenuatus		1		15	4	1	15		15	X		11		
9. E. mucronatus												2		
0. E. subtenuis	1	85	86	2	173		39		45					
1. E. pileatus													1	
2. E. subcrassus									3	X	4			
3. Rhincalanus cornutus	X		1	1			3	48	9	1	2	1	5	
4. R. nasutus	1													
5. Paracalanus aculeatus			X	3	3		1		11	3	4	1		
6. P. parvus	X													
7. P. dubia														1
8. Acrocalanus longicornis				2			1		1	X				
9. A. andersoni										1	X			1
0. A. monachus										X	X	3		
1. Calocalanus pavo				1					1	1	1	X		
2. C. plumulosus													X	
3. Clausocalanus arcuicornis	3	75	4	9	27	15	11		3	12	18	9	5	
4. C. furcatus		30		14	3		1		6	6		4	1	
5. Euaetideus giesbrechti	1		1					X	X					
6. E. acutus	5	2	3	X	11	X	4		X	X				
7. E. bradyi	13		3						X					
8. Chiridius poppei	2								X					
9. Gaetanus miles								2	X					
0. G. minor								6	3			X		
1. Euchirella bella				X			X		X	X				
2. E. venusta									X					
3. E. pulchra									X					
4. E. amoena		X	X	X	X				X					
5. E. curticauda											X			
6. E. maxima								X						
7. Pseudochirella sp.								X						
8. Chirundina streetsi												X		
9. C. indica									X					
0. Undeuchaeta plumosa									X			X	1	
1. U. intermedia									1			X		
2. Euchaeta marina		1	X	33	8	34	12		7	5	X	2		
3. E. wolfendeni		1							1	5		4	2	
4. E. media									1					
5. E. tenuis								1	1			X		
6. E. concinna													4	
7. E. longicornis	2	4												
8. E. spinosa								X						
9. Phaenna spinifera	3	X					X		1		X	X		
0. Xanthocalanus dilatus n. sp.			X											
1. Amallophora smithae n. sp.			X											
2. Scolecithrix danae		2	4	18	5	X	26	X	17	3	1	7	6	
3. S. bradyi	14	4	X		1		1							
4. Scolecithricella ctenopus	1				1					1	X			
5. S. abyssalis	8		X					1	1					
6. S. vittata	4													
7. S. tenuiserrata			6		9		2		1	2				
8. S. marginata			X		X									
9. S. tropica n. sp.	4	4			2									
0. S. sp.			X											
Scaphocalanus echinatus									X					
S. longifurca	1							X	1					
Scottocalanus securifrons												X		
S. farrani								X						
S. sedatus								X			X			
Temoropia mayumbaensis	X										X			
Metridia venusta			7											
Pleuromamma xiphias									X		X		1	
P. abdominalis	2							13	7		X	1	5	
P. indica													1	
P. quadrungulata								5	X					
P. gracilis	1							12	X			1	X	
P. borealis									X		X		1	
Centropages gracilis		1		X	X	7				X			X	
C. elongatus				X								X	X	
C. calaninus						X						1		
Lucicutia flavicornis	15	3	X		11		3	X		1			1	
L. ovalis		X		1	4				X	2	1	1		
Heterorhabdus spinifrons			2					3	1				X	
H. papilliger	5	6	10		27		9	1	1	X	X			
Haloptilus longicornis	19	12	43	X	26		50		1	X	1	X	13	
H. acutifrons	X													
H. fertilis												X		
H. ornatus									X					
H. spiniceps	X									X	X	X	X	
H. austini	1													
Augaptilus longicaudatus	X													
Euaugaptilus hecticus							2			X			X	

TABLE 2.—*List of species and number of specimens in each sub-sample*—Continued

["X" indicates the species was found during the examination of other fractions of original sample]

Species	*Hugh M. Smith*									*Stranger*	*Orsom*	*Horizon*	*Satsuma*	*Kagoshi*
	94	132	144	153	178	30	31	29	63	34	10	32	32	613
89. Arietellus setosus									X					
90. A. giesbrechti								X						
91. A. plumifer	1								X					
92. A. aculeatus									X					
93. Candacia longimana												X	X	
94. C. guggenheimi								X						
95. C. tenuimana								X						
96. C. aethiopica						X						X	X	
97. C. pachydactyla		X		X	X	X			1	X	X	X		
98. C. curta								X			X	X		
99. C. bipinnata			X		X									
100. C. varicans							1		X					
101. C. catula					X				1	X	X	X		
102. C. bispinosa				3	X					X	X		1	
103. C. simplex	X	5	X	X	1									
104. C. truncata		X		1		X			X	1	X	8	15	
105. Pontella securifer						X	X							
106. P. tenuiremis												X		
107. Labidocera detruncata						X						X		
108. Pontellina plumata		X			X	7	X		X	1	X	1		
109. Acartia danae	1	1			X									
110. A. negligens				2	2	70	5		X	X	27		X	
Unidentified copepodids	22	70	18	5	22	0	0	41	44	30	2	23	28	
Number of specimens in sub-sample	134	361	194	213	440	154	216	133	228	88	67	106	97	
Sub-sample size	1/16	1/64	1/8	1/256	1/16	1/32	1/4	1/64	1/512	1/256	1/256	1/256	1/2	
Number of copepods per cubic meter	3.6	33.4	40.8	56.4	24.8	3.7	2.3	9.2			27.8		9.3	
Number of species	34	27	26	27	31	15	25	25	55	35	31	39	29	

completing the analysis of the sub-sample, portions of the original sample were examined for species not found in the aliquot. The species in each sample are listed in table 2 along with the number of specimens of each found in the aliquot.

Representatives of most species from each station were segregated by sex and placed in labeled vials. This material will be deposited in the U.S. National Museum.

GENERAL REMARKS

Species composition

A total of 110 species of calanoid copepods was found in the samples (table 2). Of these, three species belonging to the genera *Xanthocalanus, Amallophora,* and *Scolecithricella* are described as new, and three species, *Acrocalanus andersoni, Chirundina indica,* and *Haloptilus fertilis,* are reported for the first time from the Pacific Ocean.

The collections examined were obtained from along the Equator from 120° W. to 130° E., a distance of approximately 5,800 miles (fig. 1). Many of the species were widely distributed and occurred in samples collected in the eastern Pacific (east of 170° W.) and those collected in the western Pacific (west of 170° W.). Dis regarding the small collection made at *Kago shima* station 613, the most frequently occur ring species were *Nannocalanus minor, Un dinula darwini, Clausocalanus arcuicornis,* an *Scolecithrix danae.* These four species wer present in all but one or two samples.

A study of table 2 will reveal that ther were at least 6 species which were frequentl found (4 or more samples) in the eastern Pacific, but which were not found in the sample examined from the western Pacific. One o these, *Eucalanus subtenuis,* was the most abundant copepod in three of the eastern Pacific samples and its apparent absence from th western Pacific samples is noteworthy. It i not, however, restricted to the eastern Pacific as it has been reported from Japan (Fukase 1957; Tanaka, 1956a) and from the Dutch Eas Indies (Vervoort, 1946). The other easter Pacific species have also been reported fro these two areas.

Equatorial undercurrent samples

Four of the fourteen samples examined wer obtained from within the equatorial curren (*Smith* 94, 144, 178, 31). The species composition of these samples, when compared wit mples collected from adjacent waters—north *Smith* 132), south (*Smith* 153), and above *Smith* 30) and below (*Smith* 29) the under- rrent—was not particularly distinctive. *Sco- cithricella tenuiserrata,* although apparently sent from one undercurrent sample (*Smith*), did appear in the other three samples and so in two other samples (*Smith* 63, *Stranger*) that were collected from depths where the dercurrent could be located, if present, but veral hundred miles west of its known limits. nauss (1959), has indicated that the current ay extend as far west as about 160° E.; in at event the above two samples could have en collected from the current. Even if *S. nuiserrata* is typically found within the un- ercurrent, it cannot be considered as an "indi- tor" *sensu stricto* of the current. In addi- on to the present samples, this species has en reported from near the Great Barrier eef (Farran, 1936) and from Japan (Tanaka, 53).

merical abundance

The number of copepods calculated for those llections in which a current meter was em- oyed, varied from 2.3 to 56.4 with a mean of .8 copepods per cubic meter (table 2). These ta may be compared to numerical data pre- nted by Brodsky (1952) for the northwestern cific Ocean. Using only those collections in ich closing nets were used (*Smith* 94, 132, 4, 153, 178, and 31), a mean number of 26.8 pepods per cubic meter was calculated for pths between approximately 50 and 150 ters in the eastern Pacific Ocean. Brodsky's ta included numerical abundances for seven different vertical levels. For the 50 to 100–m. level he gave a figure of 5,040 calanoids per cubic meter and for the 100 to 200–m. level, 320 per cubic meter. Nine species were present at the former level and ten at the latter level. In comparison, there were no less than 25 species in any of the aforementioned eastern Pacific closing net samples.

TAXONOMY

For each species I have given references to its occurrence in the Pacific Ocean, with the exception of those early records summarized by Giesbrecht and Schmeil (1898) and those cited by Vervoort (1946, 1957). The former reference has usually been omitted in the following sections. I have given measurements for several individuals of a species and usually at all stations where it occurred. The total-length measurements are from the tip of the forehead to the end of the furca, without regard to the telescoped portions of the abdominal segments, and are recorded in mm. unless otherwise indicated. Except for *Pseudochirella,* copepodids which could not be assigned to a species are not mentioned.

Included under Remarks are certain taxonomic or ecological notes and usually a few brief statements on the diagnostic characters of the species. It is hoped that the specific characters mentioned and the figures presented for each species will be useful to others making identifications of tropical calanoid copepods. All illustrations were made with a camera lucida.

Family CALANIDAE

Calanus tenuicornis Dana, 1849

acific records: Vervoort, 1946. Also, Yamada, 3; Johnson, 1942; Mori, 1942; Davis, 1949; Brodsky, 0; Motoda, Iizuka, and Anraku, 1950; Motoda and raku, 1951; Anraku, 1952; Honjo, 1952; Motoda and raku, 1952b; Nakai, 1952; Anraku, 1953; Tanaka, 3; Yamazi, 1953a; 1953c; Anraku, 1954a; 1954b; toda and Anraku, 1954; Tsuruta and Chiba, 1954a; 4b; Yamazi, 1954b; 1954d; Bowman, 1955; Chiba, ruta, and Maéda, 1955; Motoda and Anraku, 1955; gaya et al., 1955; Yamazi, 1955a; Chiba, 1956; Tanaka, 1956a; Heinrich, 1957a; Honjo et al., 1957; Heinrich, 1958b; Yamazi, 1958a; 1958b; Brodsky, 1959; Lindberg, 1959; Ponomareva, 1959.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	94	1 female, 1.87 mm.; 1 male, 1.80 mm.
Do	132	present.
Do	153	1 female, 1.75 mm.; 1 male, 1.56 mm.
Do	178	present.
Horizon	32	1 female, 1.68 mm.

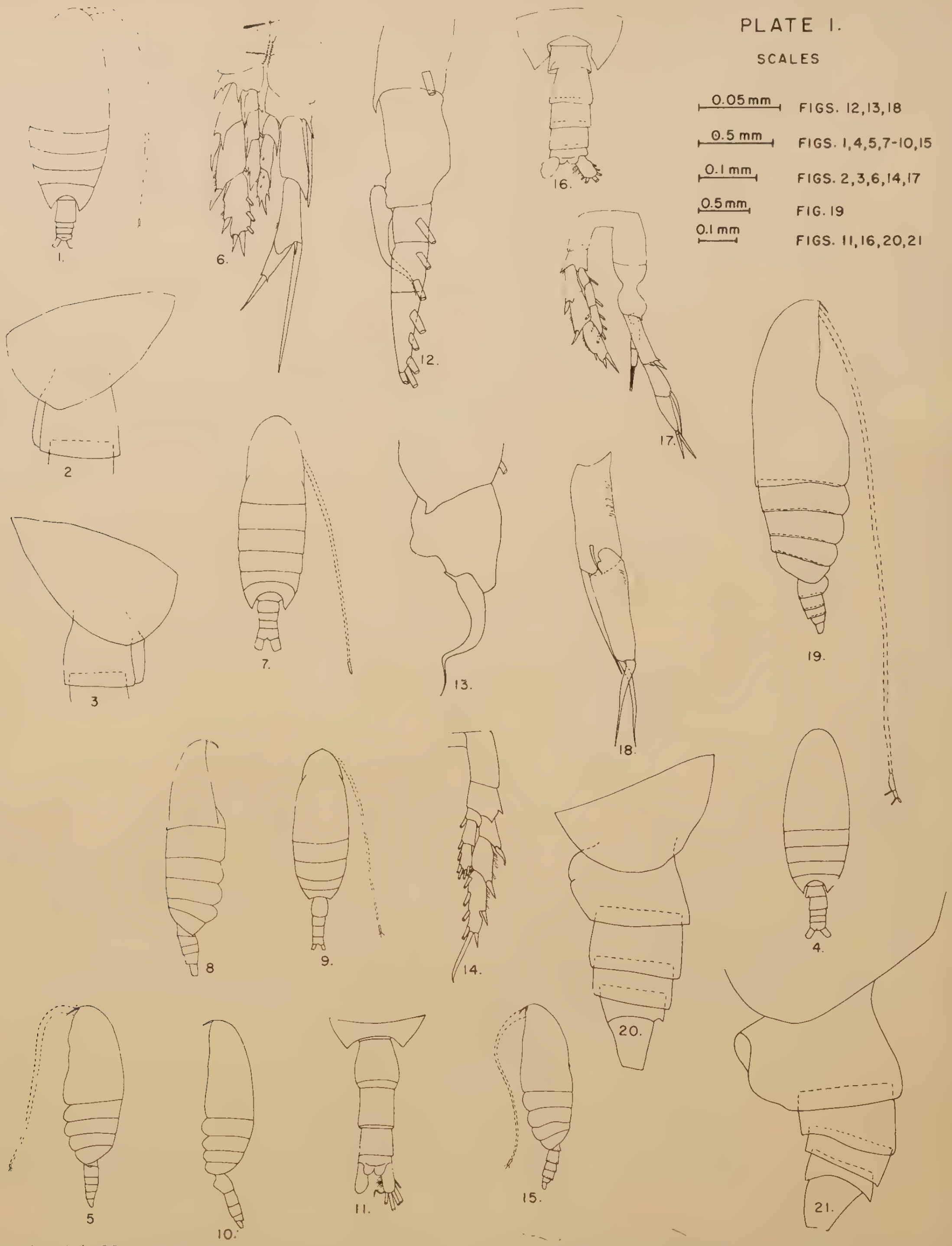


PLATE I.
SCALES
0.05 mm FIGS. 12,13,18
0.5 mm FIGS. 1,4,5,7-10,15
0.1 mm FIGS. 2,3,6,14,17
0.5 mm FIG. 19
0.1 mm FIGS. 11,16,20,21
1.
6.
12.
16.
17.
2
19.
7.
13.
3
18.
8
9.
14.
20.
4.
5
10.
11.
15.
21.

PLATE 1—(1) *Nannocalanus minor*, female, dorsal view; (2) posterior part of thorax and genital segment, left side; (3) posterior part of thorax and genital segment, right side; (4) male, dorsal view; (5) lateral view; (6) fifth pair of feet; (7) stage V female, dorsal view; (8) lateral view; (9) *Canthocalanus pauper*, female dorsal view; (10) lateral view; (11) posterior part of thorax and abdomen, dorsal view; (12) endopod of first foot lateral view; (13) first and second basipodal segments of first foot, oblique view; (14) fifth foot; (15) male, lateral view; (16) posterior part of thorax and abdomen, dorsal view; (17) fifth pair of feet; (18) distal two segments of left fifth foot; (19) *Neocalanus gracilis*, female, lateral view; (20) posterior part of thorax and abdomen, lateral view; (21) *Neocalanus robustior*, female, posterior part of thorax and abdomen, lateral view.

Remarks: Most of the present specimens ave their furcal setae eroded. Bowman (1955) as previously observed this in specimens col-ected from the northeastern Pacific. He at-ributed this erosion to protozoan parasites vhich were present in the furcae. The ma-ority of my specimens also contain these para-ites in the furcae. Bowman (1955) has fully gured *C. lighti,* a species which differs mor-hologically from *tenuicornis* only in size.

Nannocalanus minor (Claus, 1863)

(PLATE 1, FIGS. 1–8)

Pacific records: Vervoort, 1946. Also, as *Calanus inor;* Yamada, 1933a; Mori, 1937; 1942; Wilson, 942; Anraku, 1952; Chiba, 1952c; Honjo, 1952; akai, 1952; Tanaka, 1953; Yamazi, 1953a; 1953b; 953c; Anraku, 1954b; Motoda and Anraku, 1954; suruta and Chiba, 1954b; Yamazi, 1954b; 1954d; hiba, Tsuruta, and Maéda, 1955; Hida and King, 955; Motoda and Anraku, 1955; Nagaya et al., 1955; amazi, 1955d; Chiba, 1956; Tanaka, 1956a; Honjo et ., 1957; Yamazi, 1958a. As *Nannocalanus minor;* Vilson, 1950; Brodsky, 1955; Rose, 1955; Heinrich, 957b; 1958a; Brodsky, 1959.

essel:	*Station*	*Occurrence*
Hugh M. Smith	94	1 female, 1.73 mm.
Do	132	14 females, 1.56–1.70 mm.; 7 males, 1.39–1.43 mm.
Do	144	1 female, 1.73 mm.
Do	153	10 females, 1.58–1.67 mm.; 3 males, 1.44–1.46 mm.
Do	178	25 females, 1.51–1.65 mm.; 12 males, 1.31–1.51 mm.
Do	31	1 female, 1.75 mm.
Do	29	1 female, 1.80 mm.
Do	63	1 female, 1.80 mm.
Stranger	34	6 females, 1.53–1.70 mm.
Orsom	10	2 females, 1.58, 1.61 mm.; 4 males 1.24–1.46 mm.
Horizon	32	9 females (stage V), 1.53–1.70 mm.

Remarks: All the above female specimens elong to *N. minor* f. *major* (Sewell, 1929). lthough Sewell (1947) has recently recog-zed two forms of the male (f. *major* and f. *inor*), I was unable to distinguish these forms nong the above specimens. Presumably, they e all referable to f. *major* as Vervoort (1946) has reported smaller males (1.20–1.29) from one *Snellius* station (113) in Netherlands East Indies.

Canthocalanus pauper (Giesbrecht, 1888)

(PLATE 1, FIGS. 9–18)

Pacific records: Vervoort, 1946. Also, as *Calanus pauper;* Mori, 1937; 1942; Honjo, 1952; Yamazi, 1953a; 1953b; Anraku, 1954b; Johnson, 1954; Tsuruta and Chiba, 1954b; Motoda and Anraku, 1955; Nagaya et al., 1955. As *Canthocalanus pauper;* Wilson, 1942; 1950; Tanaka, 1953; Brodsky, 1955; Rose, 1955; Tanaka, 1956a; Yamazi, 1958a.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	63	1 female, 1.42 mm.
Stranger	34	1 male, 1.31 mm.
Orson	32	2 females, 1.42, 1.46 mm.; 1 male, 1.36 mm.

Remarks: This small copepod is most easily recognized by the peculiarly shaped spine on the second basipodal segment of the first pair of feet (figs. 12, 13) in the female and the structure of the fifth pair of feet (figs. 17, 18) in the male.

Neocalanus gracilis (Dana, 1849)

(PLATE 1, FIGS. 19–20)

Pacific records: Vervoort, 1946; 1957. Also, as *Calanus gracilis;* Mori, 1942; Honjo, 1952; Tsuruta and Chiba, 1954b; Motoda and Anraku, 1955; Nagaya et al., 1955; Chiba, 1956; Honjo et al., 1957. As *Neocalanus gracilis;* Tanaka, 1953; Hida and King, 1955; Tanaka, 1956a; Yamazi, 1958a.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	94	present.
Do	132	8 females (stage V), 2.34–2.48 mm.
Do	153	1 female, 3.09 mm.
Do	31	2 females, 3.33 mm.
Stranger	34	4 females, 3.01–3.06 mm.
Orsom	10	1 female, 2.96 mm.
Satsuma	32	1 female, 2.11 mm.

Remarks: Vervoort (1946) has listed the differences between this species and *Neocalanus robustior* (Giesbrecht). The adult females of *N. gracilis* are smaller (maximum 3.33) and the genital segment is less produced ventrally (fig. 20). No males were encountered in the present collections.

Neocalanus robustior (Giesbrecht, 1888)

(PLATE 1, FIG. 21)

Pacific records: Vervoort, 1946. Also, as *Calanus robustior;* Mori, 1937; Honjo, 1952; Yamazi, 1953a; Tsuruta and Chiba, 1954b; Chiba, Tsuruta, and Maéda, 1955; Nagaya et al., 1955; Chiba 1956; Honjo et al., 1957. As *Neocalanus robustior;* Wilson, 1942; 1950; Tanaka, 1953; Brodsky, 1955; Tanaka, 1956a; Yamazi, 1958a.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	153	1 female, 4.08 mm.
Do	178	1 female, 3.40 mm.
Do	63	1 female (stage V), 2.99 mm., 3 females, 3.80–3.89 mm.
Stranger	34	1 female, 3.61 mm.

Remarks: The large size (greater than 3.4 mm.) and greatly produced genital segment (fig. 21) of this species distinguishes it from *N. gracilis.* No males were found in the present samples.

Undinula vulgaris (Dana, 1849)

Pacific records: Vervoort, 1946. Also, as *Calanus vulgaris;* Yamada, 1933a; Mori, 1937; 1942; Chiba, 1952c; Honjo, 1952; Anraku, 1954b; Tsuruta and Chiba, 1954b; Motoda and Anraku, 1955; Chiba, 1956; Honjo et al., 1957. As *Undinula vulgaris;* Wilson, 1942; Johnson, 1949; Wilson, 1950; Tanaka, 1953; Johnson, 1954; Brodsky, 1955; Hida and King, 1955; Rose, 1955; Tanaka, 1956a; Yamazi, 1958a.

Vessel:	*Station*	*Occurrence*
Satsuma	32	1 male, 2.04 mm.

Remarks: Both Vervoort (1946) and Wilson (1950) speak of the great abundance of thi species in the Netherlands East Indies and nea the Hawaiian Islands, respectively. Scot (1909) also found it abundantly in the Mala Archipelago area as did Johnson (1949) i Bikini Lagoon and Tanaka (1956a) in the Iz region of Japan. In view of its extreme scar city in the present collections, it is apparentl more of an insular and nearshore species i contradistinction to *Undinula darwini,* a wide spread species in the present collections.

Undinula darwini (Lubbock, 1860)

(PLATE 2, FIGS. 1–9)

Pacific records: Vervoort, 1946. Also, as *Calanu darwini;* Yamada, 1933a; Mori, 1937; 1942; Anraku 1952; Honjo, 1952; Nakai, 1952; Yamazi, 1953a; 1953b 1953c; Anraku, 1954b; Chiba and Tsuruta, 1954; Ya mazi, 1954b; Motoda and Anraku, 1955; Nagaya et al 1955; Yamazi, 1955a; 1955d; Chiba, 1956; Honjo et al 1957; Yamazi, 1958b. As *Undinula darwini;* Wilso 1942; 1950; Tanaka, 1953; Johnson, 1954; Brodsk 1955; Rose, 1955; Tanaka, 1956a; Heinrich, 1957b 1958a; Yamazi, 1958a; 1958b.

Remarks: All female specimens of this spe cies have a group of inwardly projecting spine on the inner sides of the fifth thoracic segmen (fig. 1). Also characteristic of this sex is th shape of the genital segment, which in dorsa view, is seen to narrow anteriorly (fig. 1).

The three forms of the female of this specie (described by Sewell, 1929) are distinguishe by the shape of the left fifth thoracic margi and spinulation of the proximal segments o the first antennae. The right fifth thoraci margin in all three forms is rounded and ha

Vessel:	*Station*	*Occurrence (measurement in mm.; number of specimens in paren.)*			
		f. *typica* female	f. *symmetrica* female	f. *intermedia* female	male
Hugh M. Smith	94				(1)
Do	132		1.97 (1)		
Do	144	1.90 (1)	1.87–2.04 (7)		1.80 (3)
Do	153	1.90–2.00 (2)	1.80–1.90 (7)		present.
Do	178	present	1.84–1.90 (20)		1.60–1.67 (4)
Do	30	2.00 (2)	1.95–2.04 (4)		
Do	31	1.90–2.18 (2)	2.00 (1)		(2)
Do	29				(1)
Do	63	1.90 (1)	1.94–2.04 (5)		(8)
Stranger	34	2.04 (1)	2.04 (1)	2.07 (1)	(3)
Orsom	10			1.90 (1)	1.73 (1)
Horizon	32		2.04 (1)	1.94–2.07 (4)	
Satsuma	32	1.80 (1)		1.84–1.90 (5)	1.63 (1)

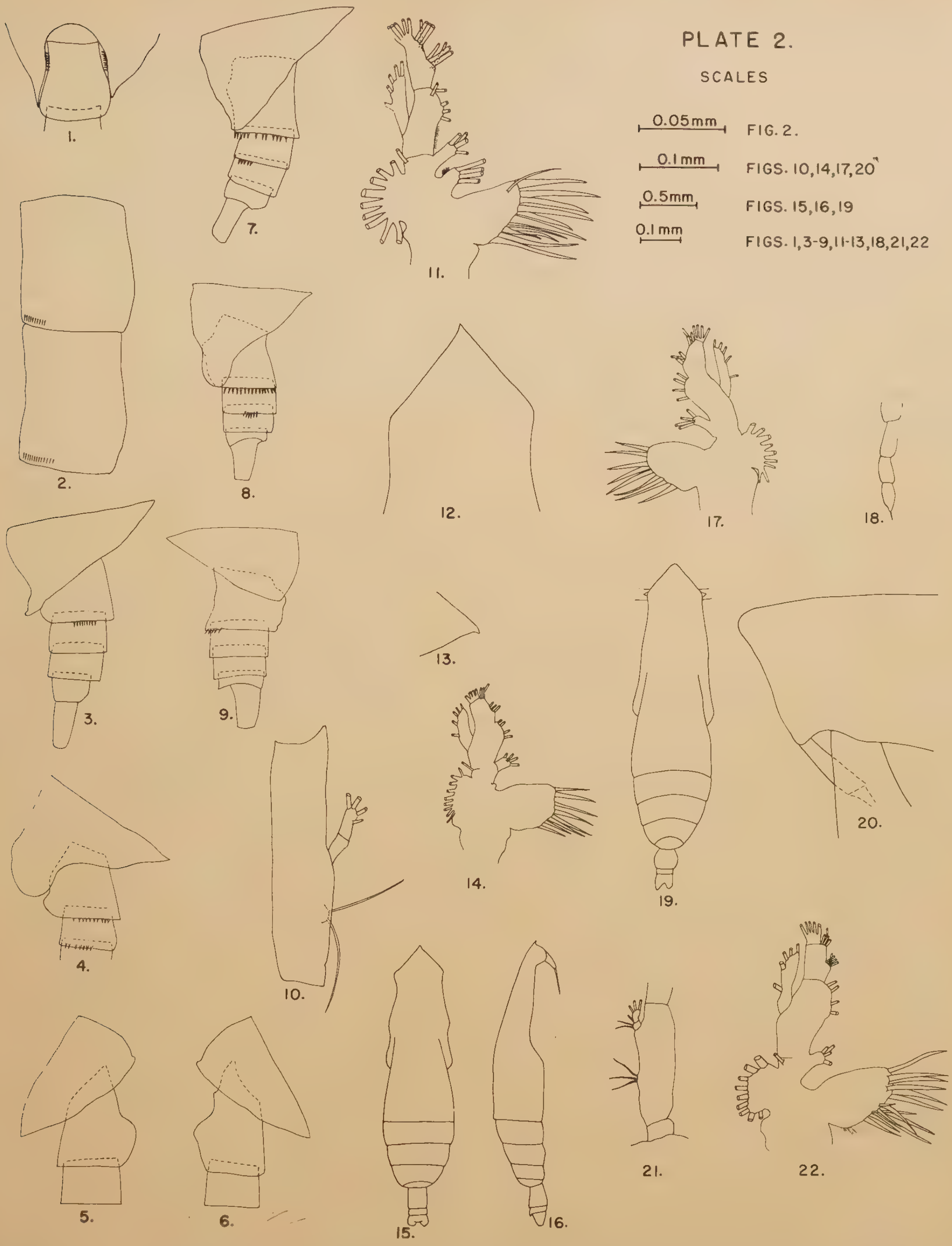


PLATE 2.
SCALES
0.05mm FIG. 2.
0.1mm FIGS. 10,14,17,20
0.5mm FIGS. 15,16,19
0.1mm FIGS. 1,3-9,11-13,18,21,22
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.
19.
20.
21.
22.

PLATE 2.—(1) *Undinula darwini* f. *typica*, female, posterior part of thorax and genital segment, dorsal view;) segments 6 and 7 of first antenna; (3) posterior part of thorax and abdomen, left side; (4) posterior part of orax and abdomen, left side; (5) *U. darwini* f. *symmetrica*, female, posterior part of thorax and genital segment, ght side; (6) posterior part of thorax and genital segment, left side; (7) *U. darwini* f. *intermedia*, female, sterior part of thorax and abdomen, left side; (8) posterior part of thorax and abdomen, left side; (9) posterior rt of thorax and abdomen, right side; (10) *Eucalanus attenuatus*, female, second basal segment and endopod mandible; (11) first maxilla; (12) *E. mucronatus*, stage IV, female, forehead, dorsal view; (13) forehead, eral view; (14) first maxilla; (15) stage V, male, dorsal view; (16) lateral view; (17) first maxilla; (18) fifth ot; (19) *E. subtenuis* var. *japonica*, female, dorsal view; (20) forehead, lateral view; (21) basal segments and dopod of mandible; (22) first maxilla.

a small notch. In forma *typica,* both segments 6 and 7 of the first antennae have a row of spinules along the distal margin (fig. 2). The left fifth thoracic margin is somewhat variable in shape. Typically, it is produced into a point which is directed ventrally (fig. 3). In a few individuals this margin was expanded and rounded (fig. 4). In forma *symmetrica,* a row of spinules is also present on segments 6 and 7 of the first antennae, but the two thoracic margins are symmetrical (figs. 5, 6). In forma *intermedia,* spinules are present on segments 3 through 7 of the first antennae, and the left fifth thoracic margin is usually more or less triangular in shape (fig. 7). In several specimens, this margin was rounded similar to tha of forma *symmetrica* (fig. 8). Most example of forma *intermedia* also had a small grou of spines situated on the left mid-lateral margi of the second abdominal segment.

Chiba (1953a) has recently discussed an presented figures of small (40–60μ) spherica bodies which he detected within the furcae o the female of this species. He considered thes objects to be eggs and analogized the "eg chamber" (furca) to the brood sac of daphnids I too have seen these bodies in the furcae o this species. They are possibly protozoan parasites but not the reproductive eggs of th species.

Family EUCALANIDAE

Eucalanus attenuatus (Dana, 1849)

(PLATE 2, FIGS. 10, 11)

Pacific records: Vervoort, 1946. Also, Yamada, 1933a; Tanaka, 1935a; Mori, 1937; Johnson, 1942; Mori, 1942; Wilson, 1942; Brodsky, 1950; Wilson, 1950; Anraku, 1952; Honjo, 1952; Tanaka, 1953; Yamazi, 1953c; Anraku, 1954b; Johnson, 1954; Tsuruta and Chiba, 1954b; Yamazi, 1954d; Brodsky, 1955; Chiba, Tsuruta and Maéda, 1955; Hida and King, 1955; Motoda and Anraku, 1955; Nagaya et al., 1955; Rose, 1955; Yamazi, 1955a; 1955d; Chiba, 1956; Tanaka, 1956a; Honjo et al., 1957; Heinrich, 1958a; 1958b; Yamazi, 1958a; Brodsky, 1959; Lindberg, 1959; Ponomareva, 1959.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	132	1 female, 3.89 mm.
Do	153	present.
Do	178	2 females, 3.61, 3.80 mm.; 1 male, 2.96 mm.
Do	30	1 female, 3.16 mm.
Do	31	5 males, 2.92–3.06 mm.
Do	63	2 females, 3.90, 4.08 mm.
Stranger	34	1 female, 3.06 mm.
Horizon	32	7 females, 3.90–4.28 mm.; 1 female (stage V) 3.20 mm.

Remarks: Vervoort (1946) noted that there were large variations in the sizes of his specimens (females, 3.55–5.80; males 2.95–4.35) from the Netherlands East Indies, but he could find no anatomical differences between the siz groups. Tanaka (1956a) likewise observe that there were large size variations (femal 4.32–6.19; male, 3.24–4.67) in the lengths o specimens obtained from the Izu region o Japan. He reported differences (shape of gen tal segment, presence of hair on female, relative lengths of segments of fifth pair of feet i the male) between the larger specimens of thi species and suggested that a northern variet may have been present. The lengths of th present specimens were not nearly so variabl as those reported by Vervoort or Tanaka.

Eucalanus mucronatus Giesbrecht, 1888

(PLATE 2, FIGS. 12–18)

Pacific records: Vervoort, 1946; 1957. Also, Yamada, 1933; Tanaka, 1935a; Honjo, 1952; Nakai, 1952 Tanaka, 1953; Yamazi, 1953a; Anraku, 1954b; Chib Tsuruta, and Maéda, 1955; Motoda and Anraku, 1955 Nagaya et al., 1955; Tanaka, 1956a; Honjo et al., 1957 Yamazi, 1958a; 1958b.

Vessel:	*Station*	*Occurrence*
Horizon	32	1 female (stage IV) 2.07 mm.; 1 ma (stage V), 2.55 mm.

Remarks: Juveniles of this species wer found in one collection. They are easily recognized by the pointed forehead, which is presen in both sexes.

Eucalanus subtenuis Giesbrecht, 1888

(Plate 2, figs. 19–21; Plate 3, figs. 1–4)

’acific records: Vervoort, 1946. Also, Mori, 1937; ıaka, 1935a; Johnson, 1942; Mori, 1942; Wilson, 2; 1950; Tanaka, 1953; 1956a; Fukase, 1957; Honjo al., 1957; Heinrich, 1958b.

sel:	*Station*	*Occurrence*
Hugh M. Smith	94	1 female, 3.12 mm.
Do	132	13 females, 2.55–2.96 mm.
Do	144	10 females, 2.40–2.60 mm.
Do	153	present.
Do	178	15 females, 2.65–2.72 mm.; 6 males, 2.45–2.52 mm.
Do	31	15 females, 2.55–2.79 mm.
Do	63	16 females, 2.69–2.96 mm.; 1 male, 2.51 mm.

Remarks: All of the present specimens are erable to *E. subtenuis* var. *japonica* Fukase, 57. This variety is distinguished from *sub- uis* chiefly by the number of setae on the ndibular palpus (both sexes) and the struc- e of the fifth feet of the male. There are etae on the mandibular palpus (fig. 21; fig. and the distal segment of the fifth foot is ger than the terminal spine (fig. 4). In *tenuis* there are 2 setae on the mandibular pus and the terminal spine of the fifth foot longer than the distal segment.

According to Fukase, Tanaka's (1935a) *E. tenuis* and Mori's (1937) *E. mucronatus* are h referable to *subtenuis* var. *japonica*.

This species was present in seven of the nples and in four of these (*Smith* 132, 144, 3, 63) it was the most abundant species.

Eucalanus pileatus Giesbrecht, 1888

(Plate 3, figs. 5–12)

’acific records: Scott, 1909; Tanaka, 1935a; Wilson, 0; Tanaka, 1953; 1956a.

ssel:	*Station*	*Occurrence*
Satsuma	32	2 females, 1.80 and 1.94 mm.

Remarks: This species closely resembles *E. bcrassus* and the two may prove to be con- ecific. Until a detailed study is made of each, it seems best to keep them separate. The females may be distinguished as follows (Pacific specimens):

1. Size. *E. pileatus*, 1.80–2.41; *E. subcrassus*, 2.23–2.82. (length data from Tanaka, 1935a; Mori, 1937; Vervoort, 1946; and present data). Farran (1936) has reported *E. subcrassus* with total lengths of 1.84–2.92 from the Great Barrier Reef. He did not record *E. pileatus*.
2. Shape of forehead. In dorsal view anterior end of forehead more produced in *E. pileatus* (fig. 7) than in *E. subcrassus* (plate 3, fig. 15).
3. Shape of genital segment. *E. pileatus*, greatest diameter at a point approximately one-half the length of the segment (fig. 10); *E. subcrassus*, greatest diameter in lower third of segment (plate 3, fig. 16).

Eucalanus subcrassus Giesbrecht, 1888

(Plate 3, figs. 13–17)

Pacific records: Vervoort, 1946. Also, Tanaka, 1935a; Mori, 1937; 1942; Wilson, 1950; Anraku, 1952; Honjo, 1952; Tanaka, 1953; Anraku, 1954b; Tsuruta and Chiba, 1954b; Brodsky, 1955; Chiba, Tsuruta, and Maéda, 1955; Motoda and Anraku, 1955; Nagaya et al., 1955; Rose, 1955; Tanaka, 1956a; Honjo et al., 1957; Yamazi, 1958a.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	63	3 females, 2.44–2.52 mm.
Stranger	34	3 females, 2.24–2.48 mm.
Orsom	10	4 females, 2.31–2.48 mm., 3 males (stage V), 2.11–2.18 mm.

Remarks: Vervoort (1946) stated that there are 4 setae on the second basal joint of the first maxilla. The present specimens, however, have 5 (fig. 17).

Rhincalanus cornutus (Dana, 1849)

(Plate 3, figs. 18–19)

Pacific records: Vervoort, 1946. Also, Yamada, 1933; Tanaka, 1935a; Mori, 1937; 1942; Wilson, 1942; 1950; Honjo, 1952; Tanaka, 1953; Anraku, 1954b; Tsuruta and Chiba, 1954b; Chiba, Tsuruta and Maéda, 1955; Hida and King, 1955; Nagaya et al., 1955; Rose, 1955;

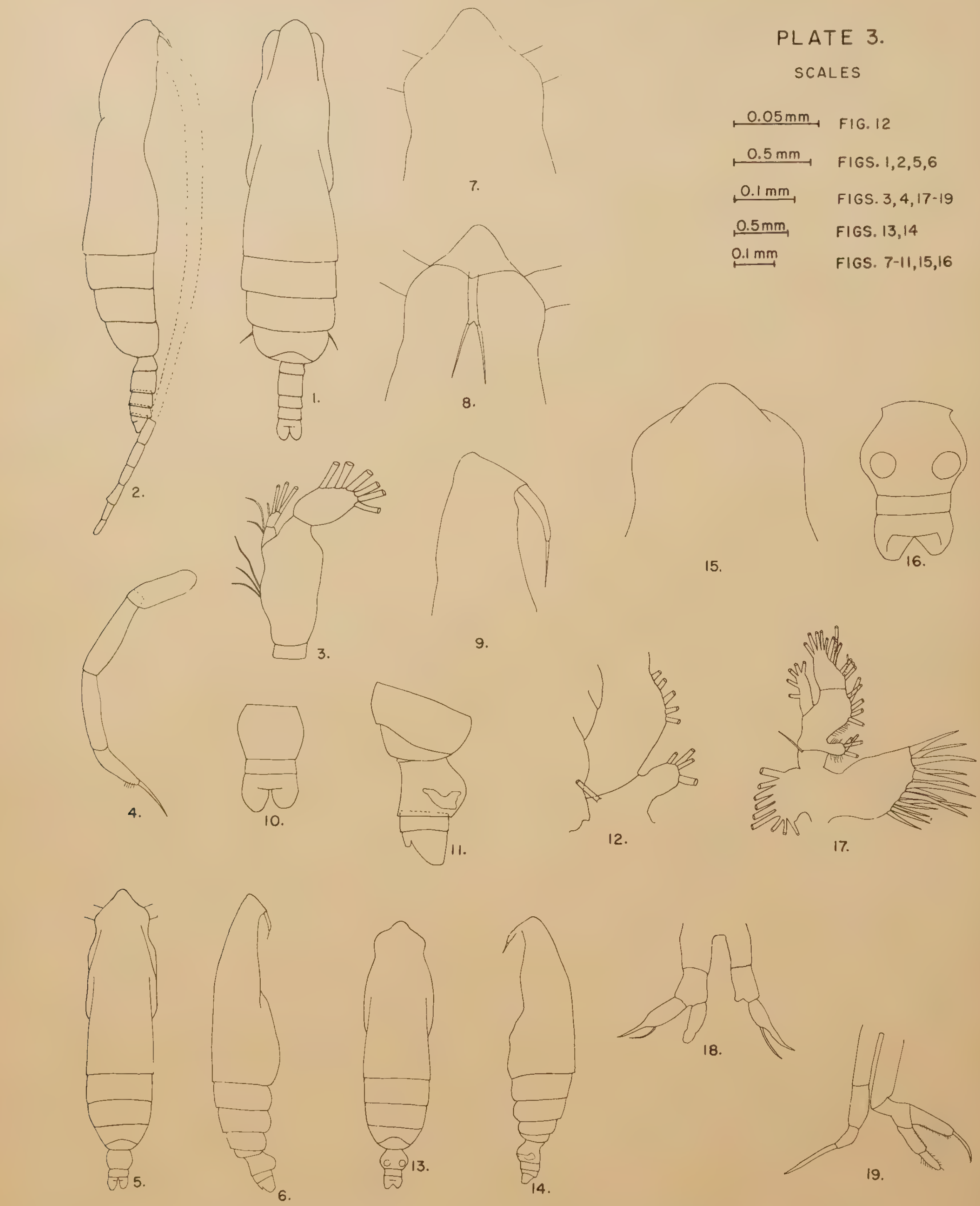


PLATE 3.
SCALES
0.05mm FIG. 12
0.5 mm FIGS. 1,2,5,6
0.1 mm FIGS. 3,4,17-19
0.5mm FIGS. 13,14
0.1 mm FIGS. 7-11,15,16
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.
19.

PLATE 3.—(1) *Eucalanus subtenuis* var. *japonica*, male, dorsal; (2) lateral; (3) mandible palpus; (4) fift foot; (5) *E. pileatus*, female, dorsal view; (6) female, lateral view; (7) forehead, dorsal view; (8) forehead ventral view; (9) forehead, lateral view; (10) abdomen, dorsal view; (11) posterior part of thorax and abdomen lateral view; (12) first maxilla (part); (13) *E. subcrassus*, female, dorsal view; (14) lateral view; (15) forehead dorsal view; (16) abdomen, dorsal view; (17) first maxilla; (18) *Rhincalanus cornutus*, stage V, male, fifth pair o feet; (19) adult male, fifth pair of feet.

hiba, 1956; Tanaka, 1956a; Honjo et al., 1957; amazi, 1958a.

essel:	*Station*	*Occurrence*
Hugh M. Smith	94	2 females, 2.79, 3.20 mm.
Do	144	1 female, 3.09 mm.
Do	153	1 male, 2.89 mm.
Do	31	2 females, 3.33; 2 males (stage V), 2.70, 2.80 mm.
Do	29	18 females, 3.20–3.33 mm.; 6 males, 2.79–2.86 mm.
Do	63	3 females, 3.09–3.24 mm.
Stranger	34	1 female, 3.09 mm.
Orsom	10	2 males, 2.69, 2.72 mm.
Horizon	32	2 females, 3.40 mm.; 1 male (stage V), 2.52 mm.
Satsuma	32	1 male, 2.95 mm.

Remarks: All of the above females belong to *R. cornutus* f. *typica* Schmaus. This species was widely distributed in the samples.

Rhincalanus nasutus Giesbrecht, 1888

Pacific records: Vervoort, 1946; 1957. Also, Yamada, 1933; Tanaka, 1935a; Johnson, 1942; Brodsky, 1950; Anraku, 1952; Honjo, 1952; Tanaka, 1953; Anraku, 1954b; 1954c; Chiba and Tsuruta, 1955; Tanaka, 1956a; Honjo et al., 1957; Heinrich, 1958a; Yamazi, 1958a.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	94	4 females, 4.08–4.37 mm.

Remarks: This species occurred in but one sample which was collected in the eastern Pacific by a closing net at a depth between 146 and 172 meters. As Vervoort (1946) mentioned, it is primarily a subsurface species.

Family PARACALANIDAE

Paracalanus aculeatus Giesbrecht, 1888

(PLATE 4, FIGS. 1–3)

Pacific records: Vervoort, 1946; 1957. Also, Yamada, 933a; 1933b; Mori, 1942; Anraku, 1952; Chiba, 1952a; 952b; Honjo, 1952; Nakai, 1952; Anraku, 1953; anaka, 1953; Yamazi, 1953c; Anraku, 1954b; Tsuruta nd Chiba, 1954b; Chiba, Tsuruta, and Maéda, 1955; otoda and Anraku, 1955; Nagaya et al., 1955; Rose, 955; Chiba, 1956; Tanaka, 1956b; Honjo et al., 1957; amazi, 1958a.

essel:	*Station*	*Occurrence*
Hugh M. Smith	144	1 female, 1.0 mm.
Do	153	2 females, 1.09, 1.17 mm.
Do	178	2 females, 1.10 mm.
Do	31	1 female, 1.10 mm.
Do	63	9 females, 1.04–1.16 mm.
Stranger	34	4 females, 1.07–1.17 mm.
Orsom	10	3 females, 1.07–1.12 mm.
Horizon	32	2 females, 1.05, 1.10 mm.

Remarks: All the present specimens belong *P. aculeatus* f. *major* Sewell, 1929. It was idely distributed in the present collections, ut no males were observed.

Paracalanus parvus (Claus, 1863)

Pacific records: Vervoort, 1946; 1957. Also, Mori, 1942; Lowe, 1936; Chiba, 1949; Kokubo, 1950; Yamazi, 1950; 1951; Anraku, 1952; Honjo, 1952; Motoda and Anraku, 1952a; Yamazi, 1952a; 1952b; 1952c; Anraku, 1953; Tanaka, 1953; Yamazi, 1953a; 1953b; 1953c; Anraku, 1954a; 1954b; Tsuruta and Chiba, 1954b; Yamazi, 1954a; 1954b; 1954c; 1954d; 1954e; Chiba, Tsuruta, and Maéda, 1955; Motoda and Anraku, 1955; Nagaya et al., 1955; Nakai, 1955; Rose, 1955; Yamazi, 1955a; 1955b; 1955c; 1955d; Chiba, 1956; Shen and Bai, 1956; Tanaka, 1956b; Honjo et al., 1957; Légaré, 1957; Yamazi, 1957; 1958a; 1958b; Brodsky, 1959; Lindberg, 1959.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	94	2 females, 0.99 mm.

Remarks: Although this is a cosmopolitan species, it was observed in but one sample. Possibly its small size permitted most of the specimens to pass through the meshes of the nets employed or perhaps it is not too abundant in the waters sampled.

Paracalanus dubia Sewell, 1912

(PLATE 4, FIGS. 4–12)

Pacific records: Rose, 1955.

Vessel:	*Station*	*Occurrence*
Kagoshima	613	1 female, 0.49 mm.

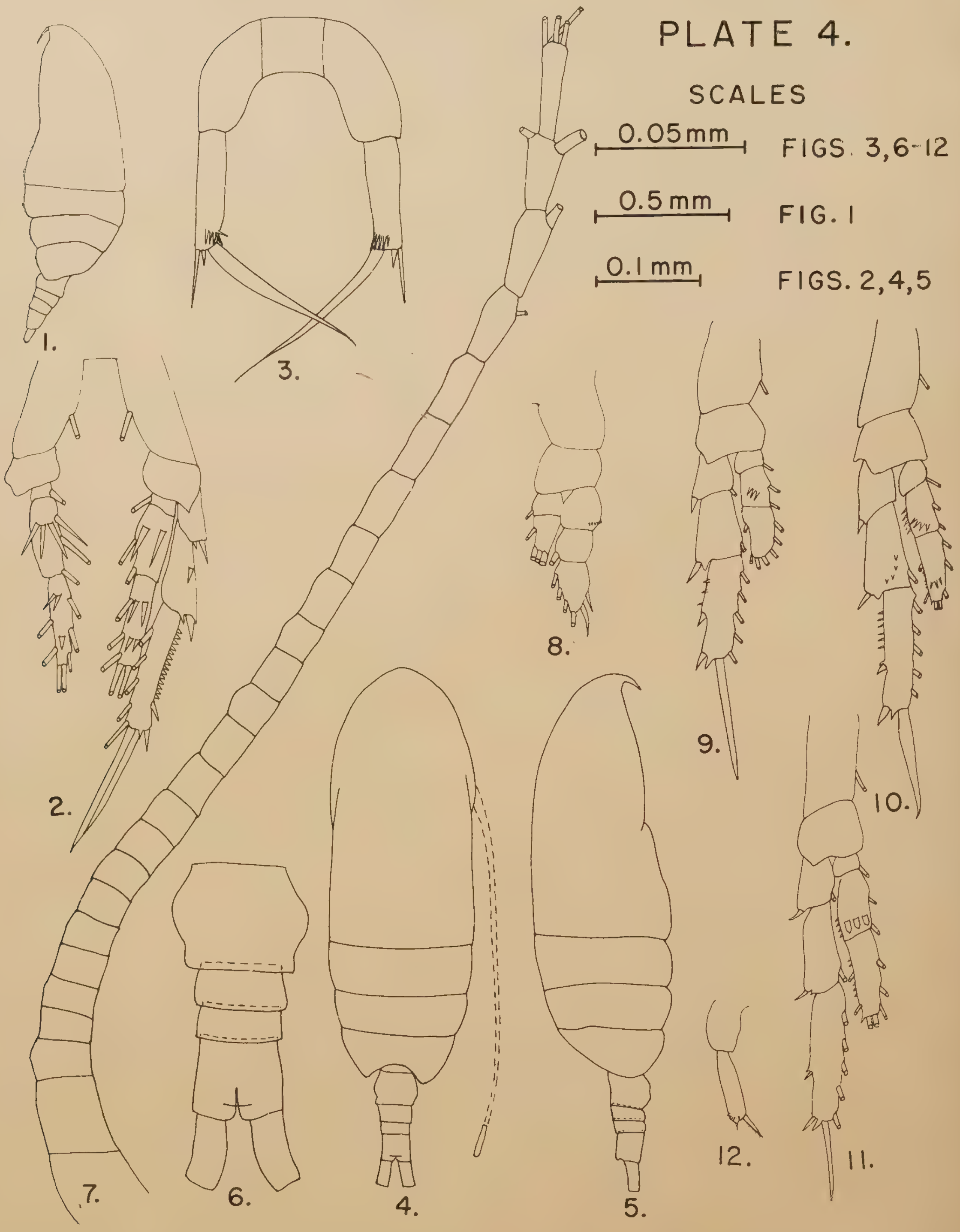


PLATE 4.
SCALES
0.05mm FIGS. 3,6-12
0.5mm FIG. 1
0.1mm FIGS. 2,4,5
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.

PLATE 4.—(1) *Paracalanus aculeatus*, female, lateral view; (2) fourth pair of feet (one exopod missing) (3) fifth pair of feet; (4) *P. dubia*, female, dorsal view; (5) lateral view; (6) abdomen, dorsal view; (7) firs antenna; (8) first foot; (9) second foot; (10) third foot; (11) fourth foot; (12) fifth foot.

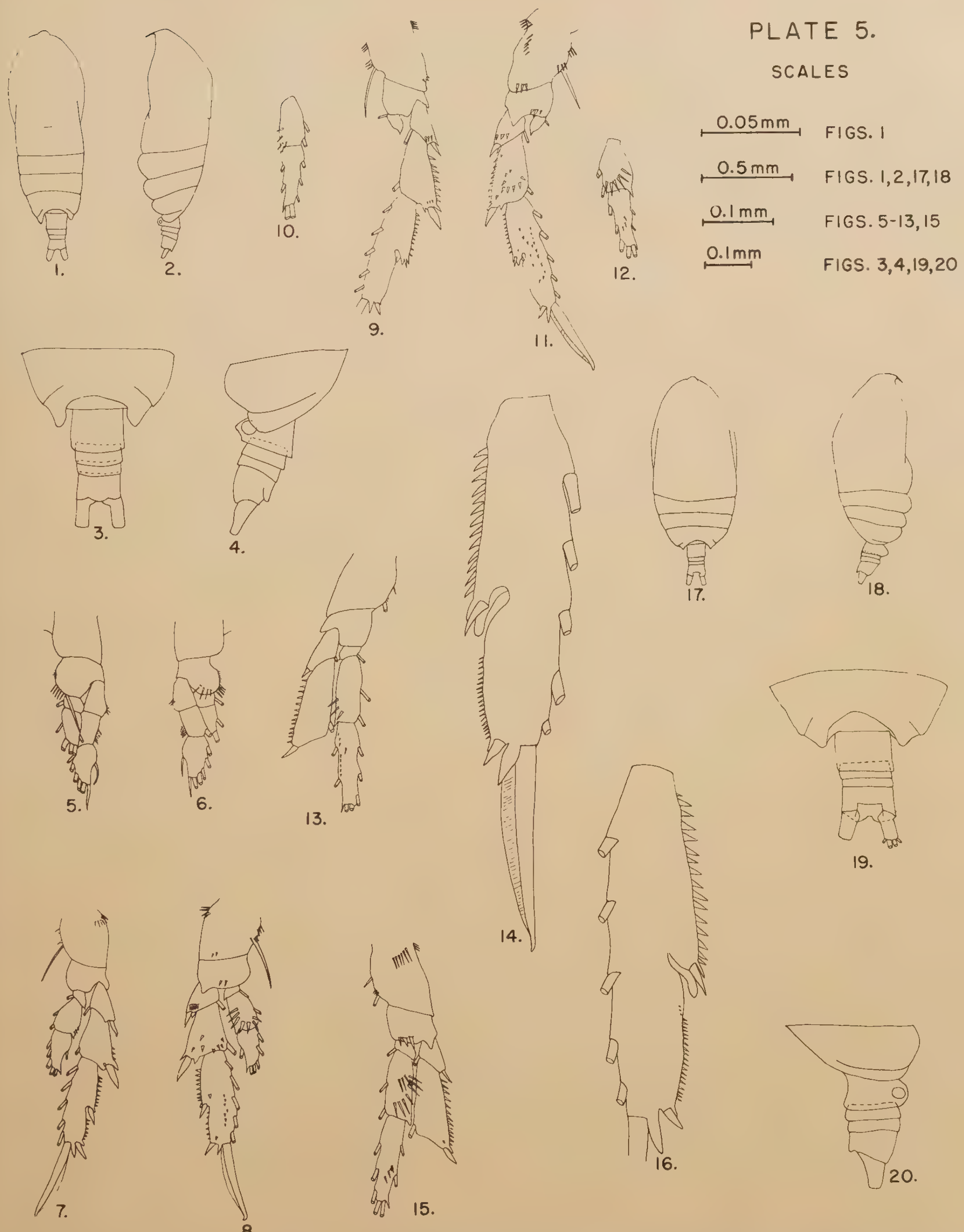


PLATE 5.
SCALES
0.05mm FIGS. 1
0.5mm FIGS. 1,2,17,18
0.1mm FIGS. 5-13,15
0.1mm FIGS. 3,4,19,20
1.
2.
10.
9.
11.
12.
3.
4.
17.
18.
5.
6.
13.
14.
19.
7.
8.
15.
16.
20.

PLATE 5.—(1) *Acrocalanus longicornis,* female, dorsal view; (2) lateral view; (3) posterior part of thorax nd abdomen, dorsal view; (4) posterior part of thorax and abdomen, lateral view; (5) first foot, anterior; (6) first oot, posterior; (7) second foot, anterior; (8) second foot, posterior; (9) third foot, anterior, without distal 2 egments of endopod; (10) distal 2 segments of endopod of third foot, anterior; (11) third foot, posterior, without istal 2 segments of endopod; (12) distal 2 segments of endopod, posterior; (13) fourth foot, anterior, without hird exopodal segment; (14) third exopodal segment of fourth foot, anterior; (15) fourth foot, posterior, without hird exopodal segment; (16) third exopodal segment of fourth foot, posterior; (17) *A. andersoni,* female, dorsal iew; (18) lateral view; (19) posterior part of thorax and abdomen, dorsal view; (20) posterior part of thorax nd abdomen, lateral view.

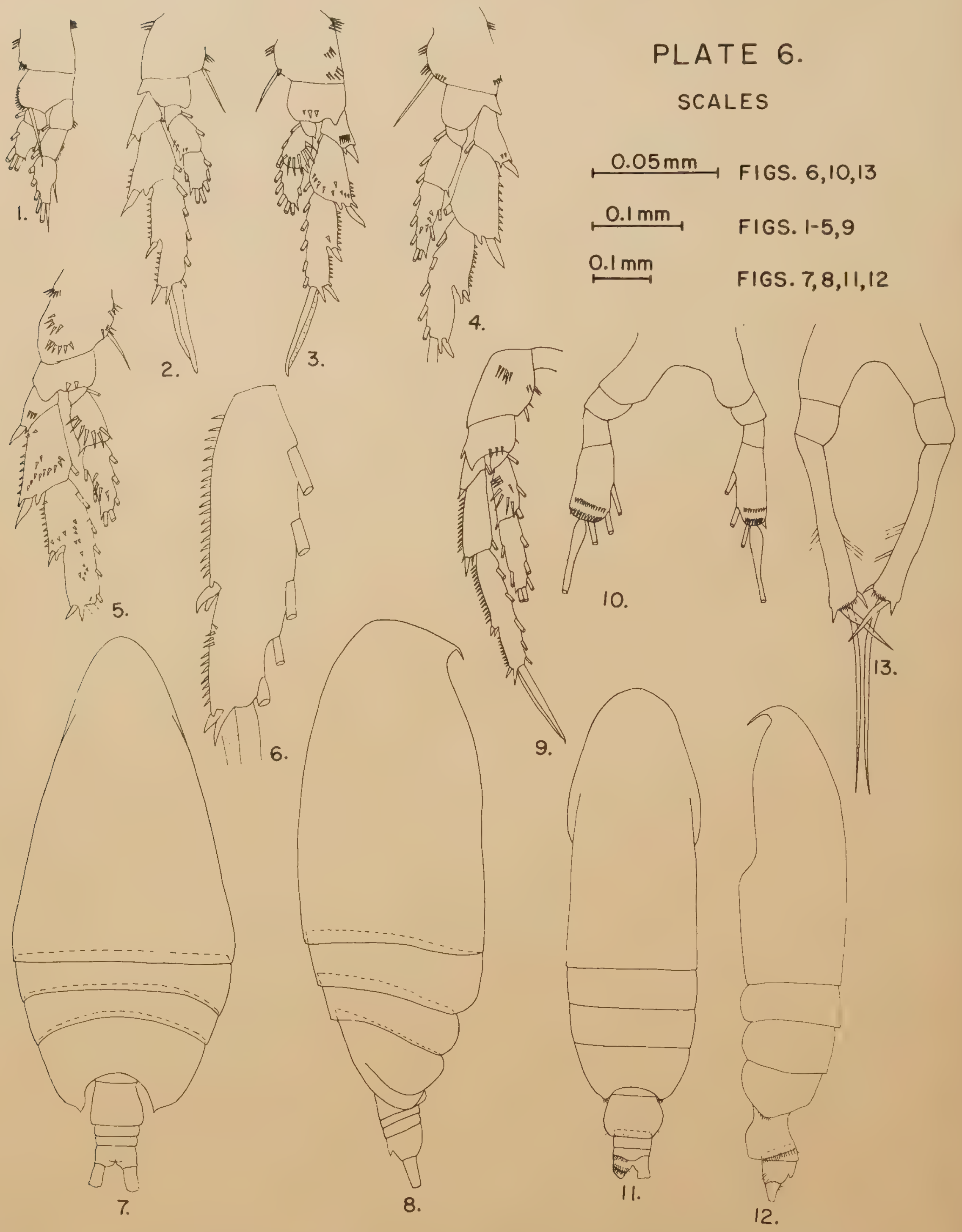


PLATE 6.
SCALES
0.05mm FIGS. 6,10,13
0.1mm FIGS. 1-5,9
0.1mm FIGS. 7,8,11,12
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.

PLATE 6.—(1) *Acrocalanus andersoni*, first foot, anterior; (2) second foot, anterior; (3) second foot, posterior; (4) third foot, anterior; (5) third foot, posterior; (6) third exopodal segment of fourth foot, posterior; (7) *A. monachus*, female, dorsal view; (8) lateral view; (9) fourth foot, posterior; (10) *Calocalanus pavo*, female, fifth pair of feet; (11) *C. plumulosus*, female, dorsal view; (12) lateral view; (13) fifth pair of feet.

Remarks: The forehead of the present speimen as well as the spination of certain of he first four pairs of swimming feet differ omewhat from Sewell's description. The fifth air of feet of Sewell's *P. serratipes* are similar o those of *P. dubia* but the former is a larger pecies (1.10 mm.).

The small spinules on the distal end of the erminal segment of the fifth feet can best be een under oil immersion. The other feet, exept the first pair, were also examined under il in order to ascertain the number of setae, urface spines and lateral teeth on the various egments.

Only one specimen was obtained and this was artly destroyed in the process of dissection.

Acrocalanus longicornis Giesbrecht, 1888

(PLATE 5, FIGS. 1–16)

Pacific records: Vervoort, 1946. Also, Yamada, 1933; Mori, 1937; 1942; Wilson, 1942; 1950; Tanaka, 1953; suruta and Chiba, 1954b; Chiba, Tsuruta and Maéda, 955; Nagaya et al., 1955; Rose, 1955; Yamazi, 1955a; anaka, 1956b; Honjo et al., 1957; Yamazi, 1958a.

essel:	Station	Occurrence
Hugh M. Smith	153	2 females, 1.20, 1.22 mm.
Do	31	1 female, 1.26 mm.
Do	63	2 females, 1.19, 1.24 mm.
Stranger	34	7 females, 1.17–1.27 mm.

Remarks: The presence of a partial suture etween the head and first thoracic segment (figs. 1, 2) and the spination of the swimming eet, particularly the number of teeth (more han 18) on the distal part of the third exopodal segment of the fourth pair of feet (figs. 14, 16), distinguished this species from others in he genus.

Acrocalanus andersoni Bowman, 1958

(PLATE 5, FIGS. 17–20; PLATE 6, FIGS. 1–6)

Pacific records: None.

Vessel:	Station	Occurrence
Stranger	34	1 female, 0.95 mm.
Orsom	10	3 females, 1.12–1.17 mm.
Kagoshima	613	1 female, 1.12 mm.

Remarks: This species was recently described from specimens obtained from the south Atlantic coast of the United States (Bowman, 1958). It is recognized by the lack of partial suture between the head and first thoracic segment (figs. 17, 18) and the number of lateral teeth (11) on the distal part of the third exopodal segment of the fourth pair of feet (fig. 6).

Acrocalanus monachus Giesbrecht, 1888

(PLATE 6, FIGS. 7–9)

Pacific records: Scott, 1909; Farran, 1936; Mori, 1937; 1942; Wilson, 1942; 1950; Tanaka, 1953; Tsuruta and Chiba, 1954b; Chiba, Tsuruta, and Maéda, 1955.

Vessel:	Station	Occurrence
Stranger	34	2 females, 1.02, 1.05 mm.
Orsom	10	1 female, 1.00 mm.
Horizon	32	3 females, 1.00–1.10 mm.

Remarks: The truncate appearance of this species in lateral view (fig. 8) readily distinguishes it from others in the genus.

Calocalanus pavo (Dana, 1849)

(PLATE 6, FIG. 10)

Pacific records: Vervoort, 1946. Also, Yamada, 1933a; Mori, 1937; Johnson, 1942; Mori, 1942; Wilson, 1942; 1950; Tanaka, 1953; Yamazi, 1953b; 1953c; Johnson, 1954; Tsuruta and Chiba, 1954b; Yamazi, 1954d; Brodsky, 1955; Chiba, Tsuruta, and Maéda, 1955; Nagaya et al., 1955; Rose, 1955; Yamazi, 1955d; Chiba, 1956; Tanaka, 1956b; Heinrich, 1957b; Honjo et al., 1957; Heinrich, 1958b; Yamazi, 1958a; 1958b.

Vessel:	Station	Occurrence
Hugh M. Smith	153	1 female, 0.85 mm.
Do	63	1 female, 1.00 mm.
Stranger	34	1 female, 1.19 mm.
Orsom	10	1 female, 0.97 mm.
Horizon	32	1 female, 1.00 mm.

Remarks: Bernard (1958) has recently revised the genus *Calocalanus* based on material collected in the Bay of Algiers. She proposed the family Calocalanidae, which consists of the genus *Calocalanus* s. str. and two new genera, *Leptocalanus* and *Dolichocera*. She has also

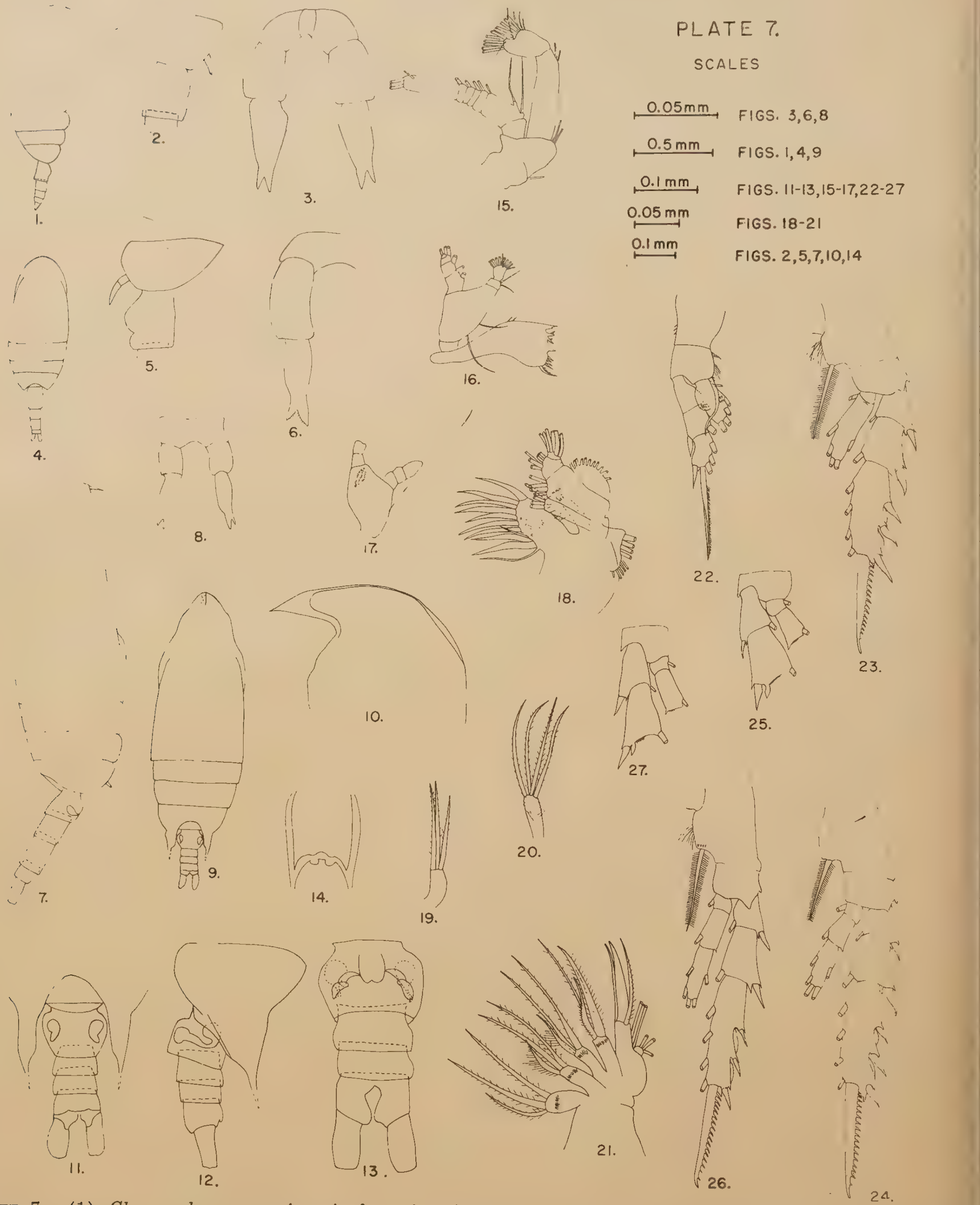


PLATE 7.
SCALES
0.05 mm FIGS. 3,6,8
0.5 mm FIGS. 1,4,9
0.1 mm FIGS. 11-13,15-17,22-27
0.05 mm FIGS. 18-21
0.1 mm FIGS. 2,5,7,10,14
1.
2.
3.
15.
4.
5.
6.
16.
22.
23.
8.
17.
18.
10.
25.
27.
20.
7.
9.
14.
19.
11.
12.
13.
21.
26.
24.

Plate 7.—(1) *Clausocalanus arcuicornis* f. *major*, female, lateral view; (2) posterior part of thorax and genital segment, lateral view; (3) fifth pair of feet; (4) *C. arcuicornis* f. *minor*, female, dorsal view; (5) posterior part of thorax and genital segment, lateral view; (6) fifth foot; (7) *C. furcatus*, female, lateral view; (8) fifth pair of feet; (9) *Euaetideus giesbrechti*, female, dorsal view; (10) forehead, lateral view; (11) posterior part of thorax and abdomen, dorsal view; (12) posterior part of thorax and abdomen, lateral view; (13) abdomen, ventral view; (14) rostrum; (15) second antenna; (16) mandible; (17) mandible palpus (other side); (18) first maxilla; (19) second inner lobe of first maxilla; (20) third inner lobe of first maxilla; (21) second maxilla; (22) first foot, anterior; (23) second foot, posterior; (24) third foot, posterior; (25) second basipodal segment and first and second segments of endopod and exopod of third foot, anterior; (26) fourth foot, posterior; (27) second basipodal segment and first and second segments of endopod and exopod of fourth foot, anterior.

escribed two new species and presented decriptions of five hitherto unknown males. *alocalanus gracilis* Tanaka, 1956, is not inluded in her revision.

Calocalanus plumulosus (Claus, 1863)

(PLATE 6, FIGS. 11–13)

Pacific records: Scott, 1909; Farran, 1929; 1936; akin and Colefax, 1940; Mori, 1942; Wilson, 1942; Anraku, 1953; Tanaka, 1953; Tanaka, 1956b; Heinrich, 1957b; 1958b; Yamazi, 1958a.

Vessel:	Station	Occurrence
Satsuma	32	2 females, 0.87 mm.

Remarks: According to Bernard's revision (see Remarks under preceding species), this species belongs to a new genus, *Leptocalanus*. The descriptions presented by Tanaka (1956b) and Bernard (1958) of the male are quite different and the two are not unispecific.

Family PSEUDOCALANIDAE

Clausocalanus arcuicornis (Dana, 1849)

(PLATE 7, FIGS. 1–6)

Pacific records: Vervoort, 1946; 1957. Also, Yamada, 933; Johnson, 1942; Mori, 1942; Brodsky, 1950; Nakai, 1952; Anraku, 1954b; Tsuruta and Chiba, 1954b; Brodsky, 1955; Chiba, Tsuruta, and Maéda, 1955; Motoda and Anraku, 1955; Nagaya et al., 1955; Rose, 1955; Chiba, 1956; Tanaka, 1956b; Heinrich, 1957b; Honjo et al., 1957; Heinrich, 1958a; Yamazi, 1958a; Brodsky, 1959; Lindberg, 1959; Ponomareva, 1959.

essel:	Station	Occurrence (*measurement in mm.; number of specimens in paren.*) f. *minor*, female	f. *major*, female	male
Hugh M. Smith	94	1.26–1.29 (2)		
Do	132	1.07–1.24 (17)		
Do	144	present	1.34–1.46 (8)	present.
Do	153	1.15–1.25 (4)	1.37 (1)	
Do	178	1.08–1.28 (21)	1.33 (1)	
Do	30		1.43–1.56 (14)	1.21–1.26 (2)
Do	31	1.19–1.31 (4)	1.42–1.53 (5)	
Do	63	1.33 (1)	1.51 (1)	
Stranger	34	1.16–1.28 (10)		
Orsom	10	1.16–1.24 (13)	1.53 (1)	
Horizon	32	1.14–1.24 (6)	1.30–1.46 (2)	
Satsuma	32	1.08–1.12 (3)		

Remarks: I have tentatively equated the females of this species to two forms which were described by Sewell, 1929. The two forms are distinguished by size and the total and relative lengths of the segments of the fifth feet. Forma *major* is large (1.30–1.60 mm.), and the fifth pair of feet is small (fig. 2). The distal segment is about twice as long as the proximal one (fig. 3). Forma *minor* is distinguished by its small size and its longer fifth feet (fig. 5). The distal and proximal segments are about equal in length.

Tanaka (1956b) has described two types of males of this species which differ in size and in the structure of the fifth feet. Although rare in the present collections, males with fifth feet referable to Tanaka's large form were found in the sample from the *Hugh M. Smith*, station 30.

Clausocalanus furcatus (Brady, 1883)

(PLATE 7, FIGS. 7–8)

Pacific records: Vervoort, 1946. Also, Mori, 1937; 1942; Wilson, 1942; Brodsky, 1950; Wilson, 1950; Nakai, 1952; Anraku, 1953; Tanaka, 1953; Yamazi, 1953c; Anraku, 1954b; Tsuruta and Chiba, 1954b; Motoda and Anraku, 1955; Nagaya et al., 1955; Rose, 1955; Chiba, 1956; Tanaka, 1956b; Honjo et al., 1957; Heinrich, 1958a.

Vessel:	Station	Occurrence
Hugh M. Smith	132	present.
Do	153	present.

Vessel:	Station	Occurrence
Do	178	2 females, 1.10, 1.12 mm.
Do	31	1 female, 1.14 mm.
Do	63	5 females, 1.00–1.17 mm.
Stranger	34	4 females, 1.12–1.19 mm.

Vessel:	Station	Occurrence
Horizon	32	3 females, 1.02–1.19 mm.
Satsuma	32	1 female, 1.05 mm.

Remarks: This species is easily distinguished from the preceding by its short genital segment (fig. 7) and very small fifth feet (figs. 7, 8).

Family AETIDEIDAE

Euaetideus giesbrechti (Cleve, 1904)

(Plate 7, figs. 9–27)

Pacific records: Vervoort, 1957. Also, as *Aetideus giesbrechti;* Johnson, 1942; Mori, 1942; Honjo, 1952; Anraku, 1954b; 1954c; Chiba, Tsuruta, and Maéda, 1955; Motoda and Anraku, 1955; Nagaya et al., 1955; Chiba, 1956; Honjo et al., 1957; Tanaka, 1957a; Yamazi, 1958a. As *Euaetideus giesbrechti*; Heinrich, 1957b; 1958a; 1958b.

Vessel:	Station	Occurrence
Hugh M. Smith	94	1 female, 1.95 mm.
Do	144	1 female, 1.95 mm.
Do	29	1 female, 1.97 mm.
Do	63	2 females, 1.97 mm.

Remarks: Vervoort (1957) has recently described a new species of *Euaetideus* (*E. australis*) as well as redescribed and figured the other three species (*E. giesbrechti, E. bradyi, E. acutus*) in this genus. The latter three species were represented in the present collections and as all three of them differ in a few details from Vervoort's descriptions, I have included a brief discussion and several figures of each of them. The chief differences between my specimens of *E. giesbrechti* and those described by Vervoort are listed below. The numbers in parenthesis are those given by Vervoort.

1. Second antennae (fig. 15). Four (3) setae on distal segment of exopod. Seven (6) setae on outer lobe and 9 (8) setae on inner lobe of endopod.

2. First maxillae (figs. 18–20). Second basal segment with 4 (5) setae. Second inner lobe with 3 (2) setae. Three (4) setae on the first segment of the endopod. It should be pointed out that Vervoort stated that the first maxilla of *E. giesbrechti* is like that of *E. australis.* The second basal segment of the first maxilla of the latter species is shown to have 4 setae, which agrees, in this respect, with the number on the present specimens.

The three species found in the present collections are distinguished by the shape of the anterior margin of the head (dorsal view); the character of the rostrum; and the posterior lateral thoracic margins. In *E. giesbrechti* the forehead is evenly rounded and the rostral plate is not visible (fig. 9). There are two small knobs between the rostral spines (fig. 14), and the posterior lateral thoracic margins have a characteristic shape (fig. 12). This species is also larger (1.95–2.00) than the other two.

Euaetideus acutus (Farran, 1929)

(Plate 8, figs. 1–2)

Pacific records: Vervoort, 1957. Also, as *Aetideus acutus;* Tanaka, 1957a.

Vessel:	Station	Occurrence
Hugh M. Smith	94	5 females, 1.65–1.70 mm.
Do	132	2 females, 1.65, 1.70 mm.
Do	144	3 females, 1.70 mm.
Do	153	1 female, 1.70 mm.
Do	178	9 females, 1.55–1.65 mm.
Do	30	1 female, 1.61 mm.
Do	31	2 females, 1.55, 1.65 mm.
Do	63	1 female, 1.60 mm.
Stranger	34	1 female, 1.60 mm.

Remarks: Certain differences were noted in the second antennae and first maxillae of the present specimens and the descriptions and figures of these appendages given by Vervoort. These differences are summarized below:

1. Second antennae. Same as that described for *E. giesbrechti.* Vervoort shows 3 setae on the terminal segment of the exopod and 6 setae on the outer lobe and 8 setae on the inner lobe of the endopod.

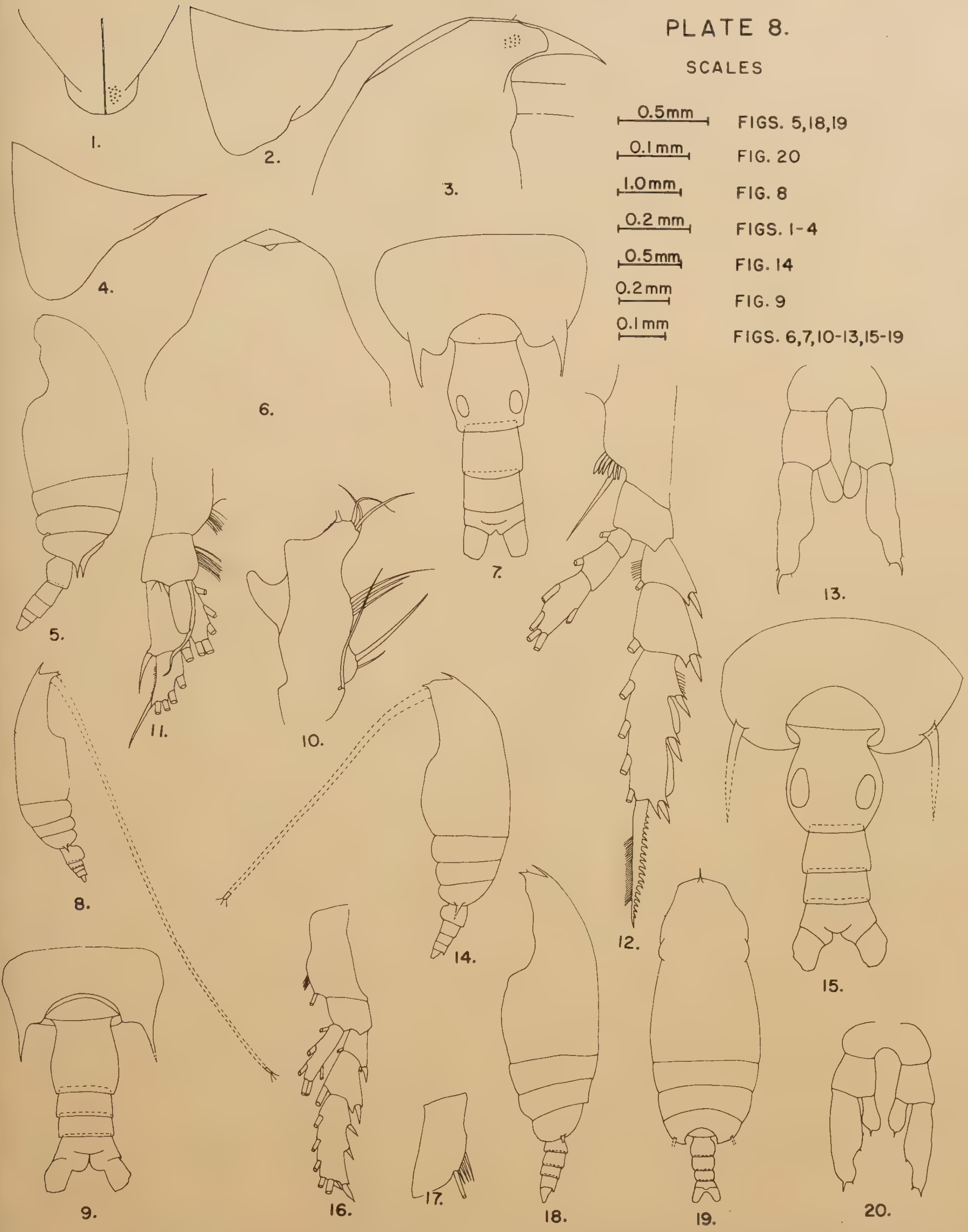


PLATE 8.
SCALES
0.5mm FIGS. 5,18,19
0.1mm FIG. 20
1.0mm FIG. 8
0.2mm FIGS. 1-4
0.5mm FIG. 14
0.2mm FIG. 9
0.1mm FIGS. 6,7,10-13,15-19
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.
19.
20.

PLATE 8.—(1) *Euaetideus acutus*, female, forehead, dorsal view; (2) fourth and fifth thoracic segments, lateral ew; (3) *E. bradyi*, female, forehead, lateral view; (4) fourth and fifth thoracic segments, lateral view; (5) *iridius poppei*, female, lateral view; (6) forehead, ventral view; (7) posterior part of thorax and abdomen, rsal view; (8) *Gaetanus miles*, female, lateral view; (9) posterior part of thorax and abdomen, dorsal view; 0) first basipodal segment of maxilliped; (11) first foot; (12) fourth foot; (13) stage V, male, fifth pair of feet; 4) *Gaetanus minor*, female, lateral view; (15) posterior part of thorax and abdomen, dorsal view; (16) second ot; (17) first basipodal segment of fourth foot; (18) stage V, male, lateral view; (19) dorsal view; (20) fifth ir of feet.

2. First maxillae. Same as that described for *E. giesbrechti.* Vervoort shows 5 setae on the second basal segment, 2 setae on the second inner lobe and 4 setae on the first segment of the endopod.

E. acutus may be identified by the large rostral plate which is visible in dorsal view (fig. 1) and the character of the posterior lateral thoracic margins (fig. 2).

Euaetideus bradyi (A. Scott, 1909)

(Plate 8, figs. 3–4)

Pacific records: Vervoort, 1957; Also, as *Aetideus bradyi;* Tanaka, 1957a.

Vessel:	Station	Occurrence
Hugh M. Smith	94	12 females, 1.60–1.65 mm.
Do	144	3 females, 1.65 mm.
Do	63	1 female, 1.70 mm.

Remarks: The second antennae differ from that figured by Vervoort in the manner described above for *E. giesbrechti.* The first maxilla of the present specimens has 4 setae on the basal segment and 3 setae on the second inner lobe. Vervoort showed 5 and 2 setae, respectively, on these parts of the maxilla. The anterior margin of the head of this species appears to be pitted similar to that of the preceding two species.

E. bradyi is distinguished from the above two species by the absence of knobs between the rostral spines and the character of the posterior lateral thoracic margins (fig. 4). In lateral view, a short hair is visible just dorsad of the base of the rostrum. I have not observed this hair in the other two species.

Chiridius poppei Giesbrecht, 1892

(Plate 8, figs. 5–7)

Pacific records: Scott, 1909; Farran, 1929; Tanaka, 1937; Wilson, 1942; Brodsky, 1950; Tanaka, 1953; 1957a.

Vessel:	Station	Occurrence
Hugh M. Smith	94	2 females, 1.59, 1.83 mm.
Do	63	1 female, 1.70 mm.

Remarks: This species was found in two samples collected in the eastern Pacific. Vervoort (1957) suggested that *C. poppei* and *gracilis* Farran, 1905 may represent differe size groups of the same species. He has al indicated how the two forms differ.

Gaetanus miles Giesbrecht, 1888

(Plate 8, figs. 8–13)

Pacific records: Scott, 1909; Farran, 1936; Wils 1942; Brodsky, 1950; Tanaka, 1953; 1957b. As *G. cundus* Esterly, 1911; Johnson, 1942.

Vessel:	Station	Occurrence
Hugh M. Smith	29	2 females, 3.40, 3.5 mm.
Do	63	2 females, 3.52 mm. 1 male (stage V), 2.89 mm.

Remarks: The female of this species is easi recognized by the elongate antennae which e ceed the furca by the last 9 segments. Accor panying the females in the collection fro *Smith* 63 was an immature male (stage V which is apparently referable to this specie The fifth feet are shown in figure 13. T adult male is undescribed, although Ester (1911) mentions that he has observed this se presumably in company with the females of h *G. secundus* (=*G. miles*).

Gaetanus minor Farran, 1905

(Plate 8, figs. 14–20)

Pacific records: Vervoort, 1957. Also, Anrak 1954b; 1954c; Tanaka, 1957b; Heinrich, 1958b.

Vessel:	Station	Occurrence
Hugh M. Smith	29	2 females, 2.18 mm.
Do	63	2 females, 2.15, 2.24 mm.; 1 male (stage V), 1.87 mm.
Horizon	32	1 female, 2.00 mm.

Remarks: The female is distinguished fro *G. miles* by the short antennae and the pre ence of numerous small spines (fig. 17) on th first basipodal segment of the fourth feet. Ros (1933) states that the endopods of the secon feet are composed of 2 segments. These end pods of the present specimens, as well as th one figured by Scott (1909), consist of only segment (fig. 16). Associated with the female in the collection from *Smith* 63 was a juveni

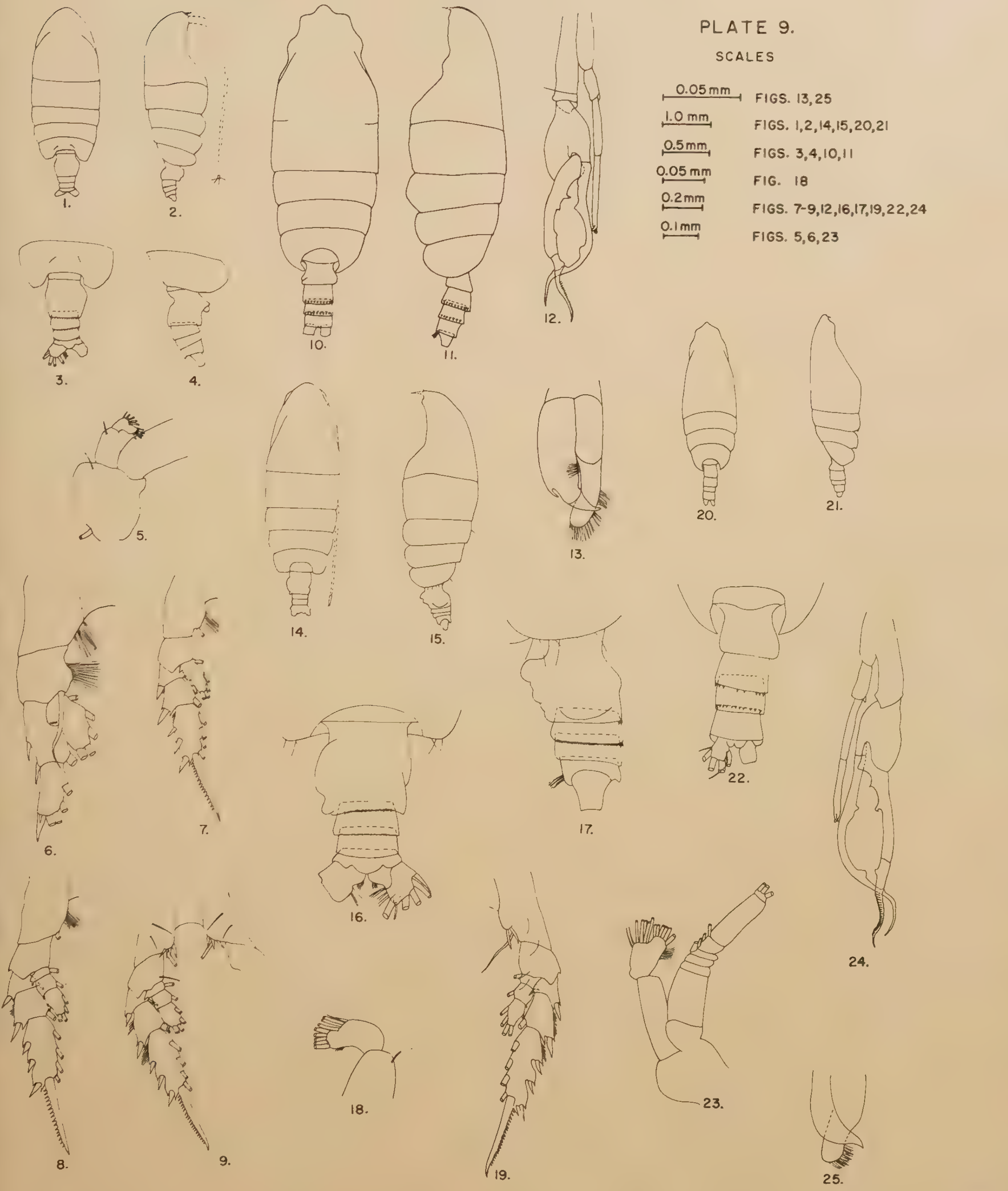


PLATE 9.
SCALES
0.05 mm FIGS. 13, 25
1.0 mm FIGS. 1, 2, 14, 15, 20, 21
0.5 mm FIGS. 3, 4, 10, 11
0.05 mm FIG. 18
0.2 mm FIGS. 7-9, 12, 16, 17, 19, 22, 24
0.1 mm FIGS. 5, 6, 23
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.
19.
20.
21.
22.
23.
24.
25.

Plate 9.—(1) *Euchirella bella,* female, dorsal view; (2) lateral view; (3) posterior part of thorax and omen, dorsal view; (4) posterior part of thorax and abdomen, lateral view; (5) endopod of second antenna; first foot; (7) second foot; (8) third foot; (9) fourth foot; (10) male, dorsal view; (11) lateral view;) fifth pair of feet; (13) terminal part of left fifth foot; (14) *E. venusta,* female, dorsal view; (15) lateral w; (16) abdomen, dorsal view; (17) abdomen, lateral view; (18) endopod of second antenna; (19) fourth t; (20) male, dorsal view; (21) lateral view; (22) abdomen, dorsal view; (23) second antenna; (24) fifth pair feet; (25) terminal part of left fifth foot.

male (stage V), which is apparently referable to this species (figs. 18–20). The male of this species has been hitherto unknown.

Euchirella bella Giesbrecht, 1888

(PLATE 9, FIGS. 1–13)

Pacific records: Vervoort, 1949; Wilson, 1950.

Vessel:	Station	Occurrence
Hugh M. Smith	153	2 females, 3.90, 4.18 mm.; 1 male, 3.33 mm.
Do	31	2 females, 3.80 mm.; 1 male, 3.36 mm.
Do	63	1 female, 3.80 mm.
Stranger	34	1 female, 3.80 mm.

Remarks: The species of female *Euchirella* are distinguished by the shape of the genital segment, number of setae on the endopod of the second antennae and the spination of the first basipodal segment of the fourth pair of feet. The males are identified by the structure of the fifth feet. The genital segment of *E. bella* is nearly symmetrical in dorsal view (figs. 1, 3) and is produced in ventral view (figs. 2, 4). The second segment of the endopod of the second antennae in the specimens examined has 5 setae on the outer and 5 setae on the inner lobe (fig. 5). Giesbrecht and Schmeil (1898) state that there are 6 and 5 setae on these respective lobes. The males in the present collections have 6 setae on the external lobe and 7 on the internal lobe, the 2 most internal ones being very small and slender. Vervoort (1949) indicated that there were 6 setae on each lobe. The number of spines on the first basipodal segment of the fourth feet is variable. Some specimens have 5 on each side and others have 4 on one side and 3 on the other (fig. 9). Scott (1909) and Sewell (1947) have also noted a variable number of spines on this segment.

Wilson (1950) has erroneously synonymized *E. amoena* with this species. See discussion of this under *E. amoena* below.

Euchirella venusta Giesbrecht, 1888

(PLATE 9, FIGS. 14–25)

Pacific records: Scott, 1909; Farran, 1929; Vervoort, 1949; Wilson, 1950; Tanaka, 1953; 1957b.

Vessel:	Station	Occurrence
Hugh M. Smith	63	4 females, 4.37–4.84 mm.; 1 male, 3.80 mm.

Remarks: The female is identified by the knob-like protrusion from the left posterior margin of the genital segment (fig. 16); the presence of 4 setae on the inner lobe and 5 setae on the external lobe of the endopod of the second antennae (fig. 18); and the two long spines on the first basipodal segments of the fourth pair of feet. Sewell (1947) has recently described the male, additional figures of which are given herein (figs. 20–25). The second antennae (fig. 23) have 6 setae on the outer lobe and 7 setae on the inner lobe, 2 of which are small. Sewell reported 6 setae on each lobe. The structure of the fifth feet agrees quite well with Sewell's figure of this appendage.

Euchirella pulchra (Lubbock, 1856)

(PLATE 10, FIGS. 1–4)

Pacific records: Esterly, 1905; Scott, 1909; Johnson, 1942; Wilson, 1942; Davis, 1949; Vervoort, 1949; Brodsky, 1950; Wilson, 1950; Tanaka, 1953; 1957b.

Vessel:	Station	Occurrence
Hugh M. Smith	63	1 female, 3.42 mm.

Remarks: The genital segment is produced into a rounded swelling to the left (fig. 2). The second segment of the endopod of the second antennae has 6 setae on each lobe (fig. 3). This is the number reported also by Tanaka (1957b), but Giesbrecht and Schmeil (1898) and Vervoort (1952) stated that the internal lobe has 5 setae. Possibly the very small, innermost seta on the internal lobe was overlooked. An additional identification character is the presence of 2 spines on the first basipodal segment of the fourth pair of feet (fig. 4).

Euchirella amoena Giesbrecht, 1888

(PLATE 10, FIGS. 5–10)

Synonymy

Euchirella amoena Giesbrecht, 1888, Atti Acc. Lincei. Rend., Ser. 4, 4, sem. 2: 336.

Euchirella brevis, Sars, 1905. Bull. Mus. Oceanogr., Monaco, 26: 12.

Euchirella bella (partim), Wilson, 1950, U.S.N.M. Bull. 100, 14: 218.

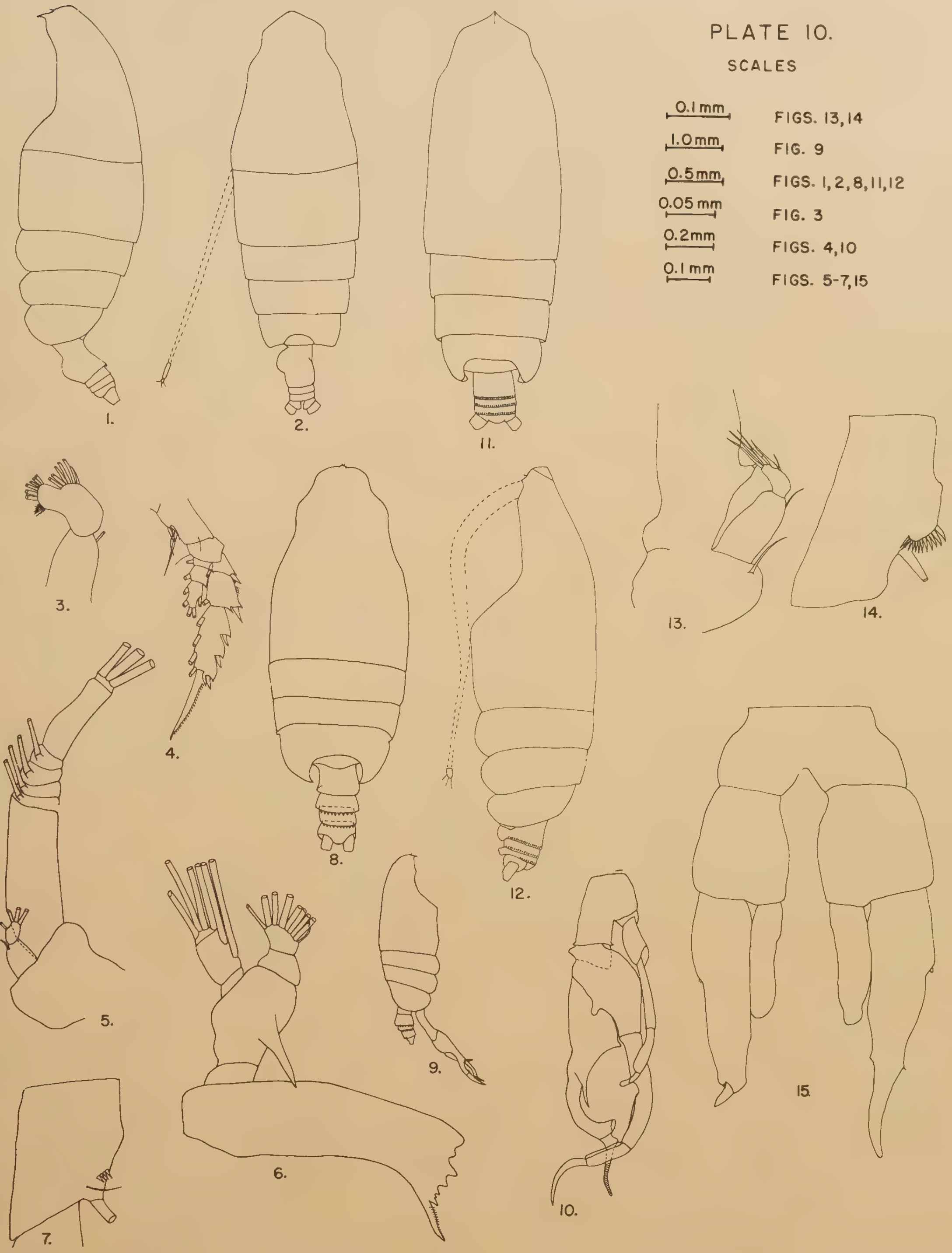


PLATE 10.
SCALES
0.1 mm FIGS. 13, 14
1.0 mm FIG. 9
0.5 mm FIGS. 1, 2, 8, 11, 12
0.05 mm FIG. 3
0.2 mm FIGS. 4, 10
0.1 mm FIGS. 5-7, 15
1.
2.
11.
3.
4.
8.
12.
13.
14.
5.
6.
9.
10.
15.
7.

PLATE 10.—(1) *Euchirella pulchra,* female, lateral view; (2) dorsal view; (3) endopod of second antenna; (4) fourth foot; (5) *E. amoena,* female, second antenna; (6) mandible; (7) first basipodal segment of fourth oot; (8) male, dorsal view; (9) lateral view; (10) fifth pair of feet; (11) *E. curticauda,* female, dorsal view; (12) lateral view; (13) endopod of second antenna; (14) first basipodal segment of fourth foot; (15) *E. maxima,* tage V, male, fifth pair of feet.

Pacific records: Esterly, 1905; Scott, 1909; Farran, 1929; Mori, 1937; Wilson, 1942; Brodsky, 1950; Wilson, 1950; Tanaka, 1953; Chiba, Tsuruta, and Maéda, 1955; Nagaya et al., 1955; Chiba, 1956; Tanaka, 1957b; Yamazi, 1958a.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	132	1 male, 3.20 mm.
Do	144	1 female, 3.70 mm.
Do	153	2 females, 3.61, 3.70 mm.; 3 males, 3.33 mm.
Do	178	1 female, 3.80 mm.
Do	63	1 male, 3.33 mm.

Remarks: Fleminger (1956) is no doubt correct in placing Sars' (1905) *brevis* (described from female) in synonymy with Giesbrecht's (1888) *amoena* (described from male). This synonymy is further substantiated by Mori's (1937) description of the female of *amoena*. Although Mori did not describe the fourth pair of feet, the total length, abdomen-cephalothorax ratio, length of the first antennae, length of the endopod of the second antennae and the number of setae on the distal segment of the endopod of the second antennae clearly establish that Mori's *E. amoena* and Sars' *E. brevis* are unispecific.

As Fleminger has stated, Wilson's synonymy of *E. amoena* under *E. bella* is an error. The male of *E. bella* was described by Sewell (1947) and Vervoort (1949); neither author was cited by Wilson. It should be noted, however, that Dr. Wilson's paper was published nine years after his death.

Euchirella curticauda Giesbrecht, 1888

(PLATE 10, FIGS. 11–14)

Pacific records: Esterly, 1906; Scott, 1909; Johnson, 1942; Mori, 1942; Wilson, 1942; Davis, 1949; Brodsky, 1950; Wilson, 1950; Anraku, 1952; Tanaka, 1953; 1957b.

Vessel:	*Station*	*Occurrence*
Orsom	10	2 females, 3.52, 3.62 mm.

Remarks: This species is recognized by the presence of a crest, absence of a rostrum (fig. 12) and the presence of a comb of spines on the first basipodal segment of the fourth pair of feet (fig. 14).

Euchirella maxima Wolfenden, 1905

(PLATE 10, FIG. 15)

Pacific records: Scott, 1909; Wilson, 1950.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	29	1 female (stage V), 5.79 mm.; 1 male (stage V), 5.70 mm.

Remarks: A male and female were obtained in the 500 m. collection made at the above station. Both sexes have a crest on the forehead. Sewell (1929) has described the stage V individuals of this species.

Pseudochirella sp.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	29	4 juveniles, 6.93–7.14 mm.

Remarks: These large juvenile copepods could not be assigned to a species. They were obtained from the 500–meter plankton tow.

Chirundina streetsi Giesbrecht, 1895

(PLATE 11, FIGS. 1–4)

Pacific records: Esterly, 1906; Scott, 1909; Farran, 1929; Johnson, 1942; Brodsky, 1950; Wilson, 1950; Tanaka, 1953; 1957b.

Vessel:	*Station*	*Occurrence*
Horizon	32	1 female, 4.94 mm.

Remarks: This species is distinguished from the following one by its large size, pronounced crest on forehead (fig. 1), and the presence of 2 spines on the first exopodal segment of the first feet (fig. 4).

Chirundina indica Sewell, 1929

(PLATE 11, FIGS. 5–20)

Pacific records: None.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	63	1 female, 4.66 mm.

Remarks: I have compared in some detail (figs. 5–20) the present species with the descriptions of *C. indica* provided by Sewell (1929, 1947). On the basis of his description the latter species is distinguished from *C.*

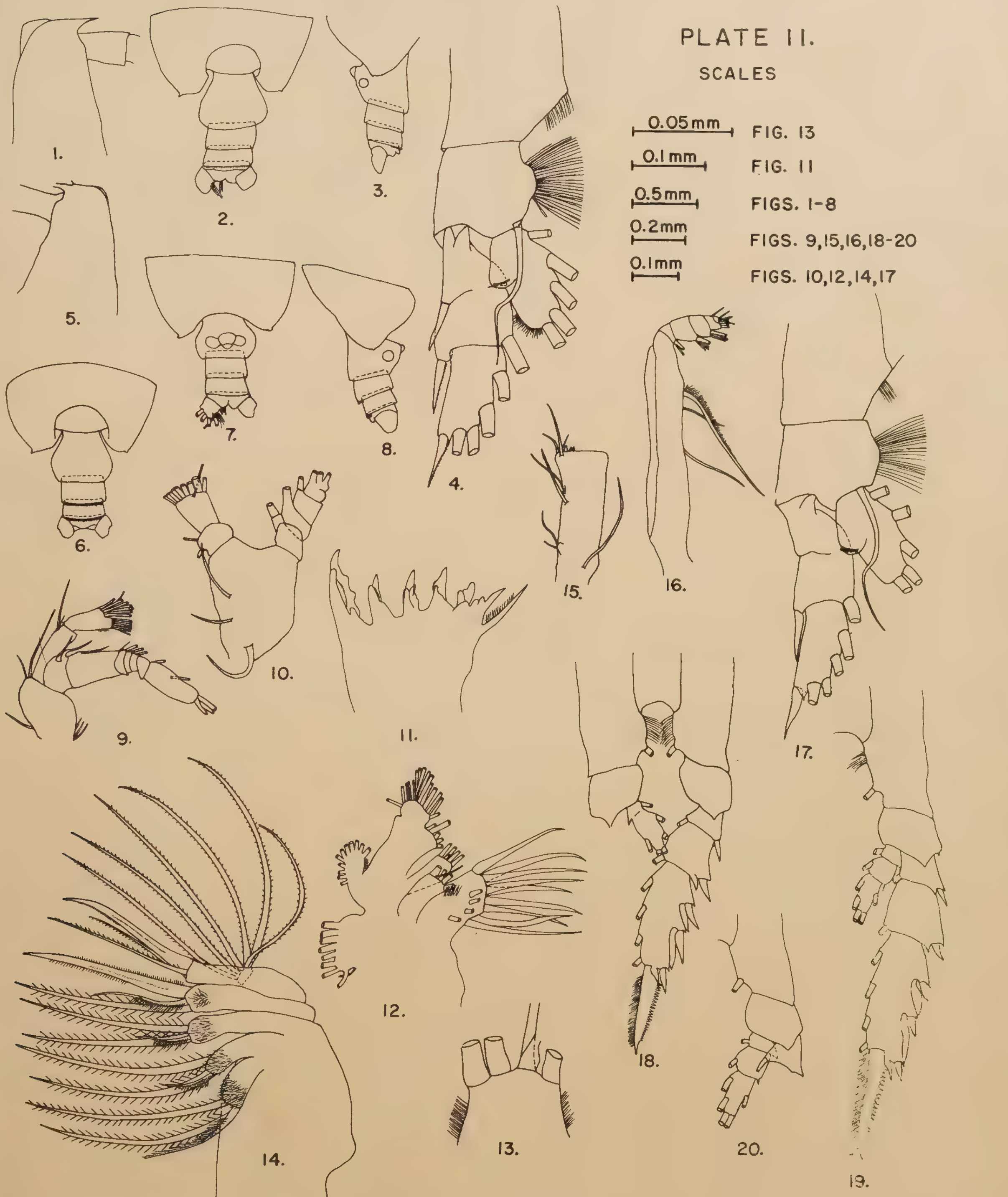


PLATE 11.
SCALES
0.05 mm FIG. 13
0.1 mm FIG. 11
0.5 mm FIGS. 1-8
0.2 mm FIGS. 9,15,16,18-20
0.1 mm FIGS. 10,12,14,17
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.
19.
20.

PLATE 11.—(1) *Chirundina streetsi*, female, forehead, lateral view; (2) posterior part of thorax and abdomen, dorsal view; (3) abdomen, lateral view; (4) first foot; (5) *C. indica*, forehead, lateral view; (6) posterior part of thorax and abdomen, dorsal view; (7) posterior part of thorax and abdomen, ventral view; (8) posterior part of thorax and abdomen, lateral view; (9) second antenna; (10) mandible palpus; (11) gnathal lobe of mandible; (12) first maxilla; (13) terminal part of third inner lobe of first maxilla; (14) second maxilla; (15) first basipodal segment of maxilliped; (16) distal part of maxilliped; (17) first foot; (18) second pair of feet (one exopod and one endopod missing); (19) third foot; (20) fourth foot (distal part of exopod missing).

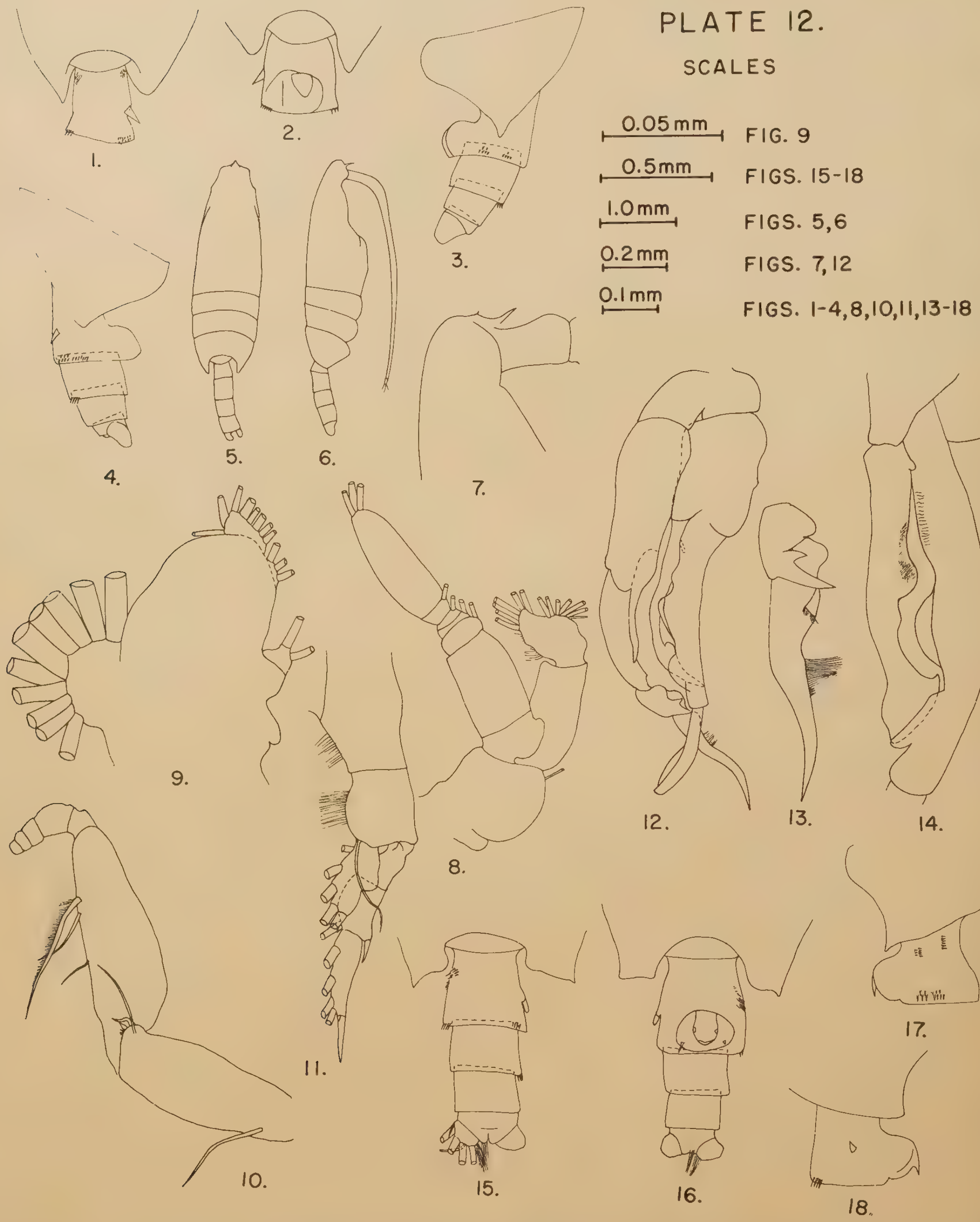


PLATE 12.
SCALES
0.05 mm FIG. 9
0.5 mm FIGS. 15-18
1.0 mm FIGS. 5, 6
0.2 mm FIGS. 7, 12
0.1 mm FIGS. 1-4, 8, 10, 11, 13-18
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.

PLATE 12.—(1) *Undeuchaeta plumosa,* female, genital segment, dorsal view; (2) ventral view; (3) posterior part of thorax and abdomen, left side; (4) posterior part of thorax and abdomen, right side; (5) male, dorsal view; (6) lateral view; (7) forehead, lateral view; (8) second antenna; (9) first maxilla (part); (10) maxilliped (setae on distal part omitted); (11) first foot; (12) fifth pair of feet; (13) terminal part of left fifth foot; (14) right fifth foot (part); (15) *U. intermedia,* female, dorsal view; (16) abdomen, ventral view; (17) genital segment, left side; (18) genital segment, right side.

streetsi by its low crest, the smoothly rounded posterior thoracic margins and the presence of but 1 external spine on the first exopodal segment of the first feet. Except for the posterior thoracic margins, which have 1 small projection (figs. 7–9), my specimen agrees with Sewell's *indica*. In details of the mouth parts, two minor differences were noted. Sewell's specimens have 6 setae on the outer lobe of the second antenna, while the present specimen has (fig. 10); the exopod of the mandible has 9 setae (Sewell probably referred to the distal segment); the present specimen has 10, one of which is extremely small (fig. 11).

The projections on the posterior thoracic margins may be a variable character as Vervoort (1957) has observed in several species of a related genus, *Undeuchaeta*. It seems best therefore to refer the present species to *C. indica*.

Undeuchaeta plumosa (Lubbock, 1856)

(Plate 12, figs. 1–14)

Pacific records: Vervoort, 1957. Also, Brodsky, 1950; Heinrich, 1957b; Tanaka, 1957b.

Vessel:	Station	Occurrence
Hugh M. Smith	63	1 male, 3.52 mm.
Horizon	32	1 female, 3.47 mm.
Satsuma	32	1 female, 3.41 mm.

Remarks: The female is distinguished by the presence of a spine on the right side of the genital segment (figs. 1, 2) near the dorsal surface, and the male by the structure of the fifth feet (figs. 12–14).

Undeuchaeta intermedia A. Scott, 1909

(Plate 12, figs. 15–18)

Pacific records: Vervoort, 1957. Also, Johnson, 1942; Brodsky, 1950 (as *U. bispinosa*)

Vessel:	Station	Occurrence
Hugh M. Smith	63	4 females, 3.99–4.28 mm.
Horizon	32	3 females, 3.99–4.08 mm.

Remarks: The large ventral spine-like protrusion of the genital segment in the female (figs. 17, 18) distinguishes this species from the preceding one.

Family EUCHAETIDAE

Euchaeta marina (Prestandrea, 1833)

(Plate 13, fig. 1)

Pacific records: Scott, 1909; Marukawa, 1921; Yamada, 1933b; Mori, 1937; Dakin and Colefax, 1940; Mori, 1942; Wilson, 1942; Brodsky, 1950; Motoda, Iizuka, and Anraku, 1950; Wilson, 1950; Anraku, 1952; Honjo, 1952; Nakai, 1952; Anraku, 1953; Chiba, 1953b; Tanaka, 1953; Anraku, 1954b; Tsuruta and Chiba, 1954b; Chiba, Tsuruta, and Maéda, 1955; Motoda and Anraku, 1955; Nagaya et al., 1955; Rose, 1955; Chiba, 1956; Heinrich, 1957b; Honjo et al., 1957; Gilmartin, 1958; Heinrich, 1958a; Tanaka, 1958; Yamazi, 1958a; Lindberg, 1959.

Vessel:	Station	Occurrence
Hugh M. Smith	132	1 male, 3.12 mm.
Do	144	1 female, 3.61 mm.
Do	153	2 females, 3.32, 3.42 mm.
Do	178	1 female, 3.06 mm.
Do	30	3 females, 2.96–3.06 mm.;1 male, 2.99 mm.
Do	31	present.
Do	63	4 females, 3.40–3.60 mm.; 1 male, 3.37 mm.
Stranger	34	4 females, 3.13–3.26 mm.; 5 males, 3.06–3.23 mm.
Orsom	10	3 females, 3.13–3.23 mm.
Horizon	32	2 females, 3.13, 3.23 mm.

Remarks: This is probably the most widespread species in the genus. It occurred in ten of the present samples and in two (*Smith* 153 and 30), it comprised a fairly significant percentage of the total number of copepods.

Euchaeta wolfendeni A. Scott, 1909

(Plate 13, figs. 2–9)

Pacific records: Farran, 1936; Mori, 1937; Wilson, 1950; Honjo, 1952; Tanaka, 1953; Tsuruta and Chiba, 1954b; Chiba, Tsuruta, and Maéda, 1955; Nagaya et

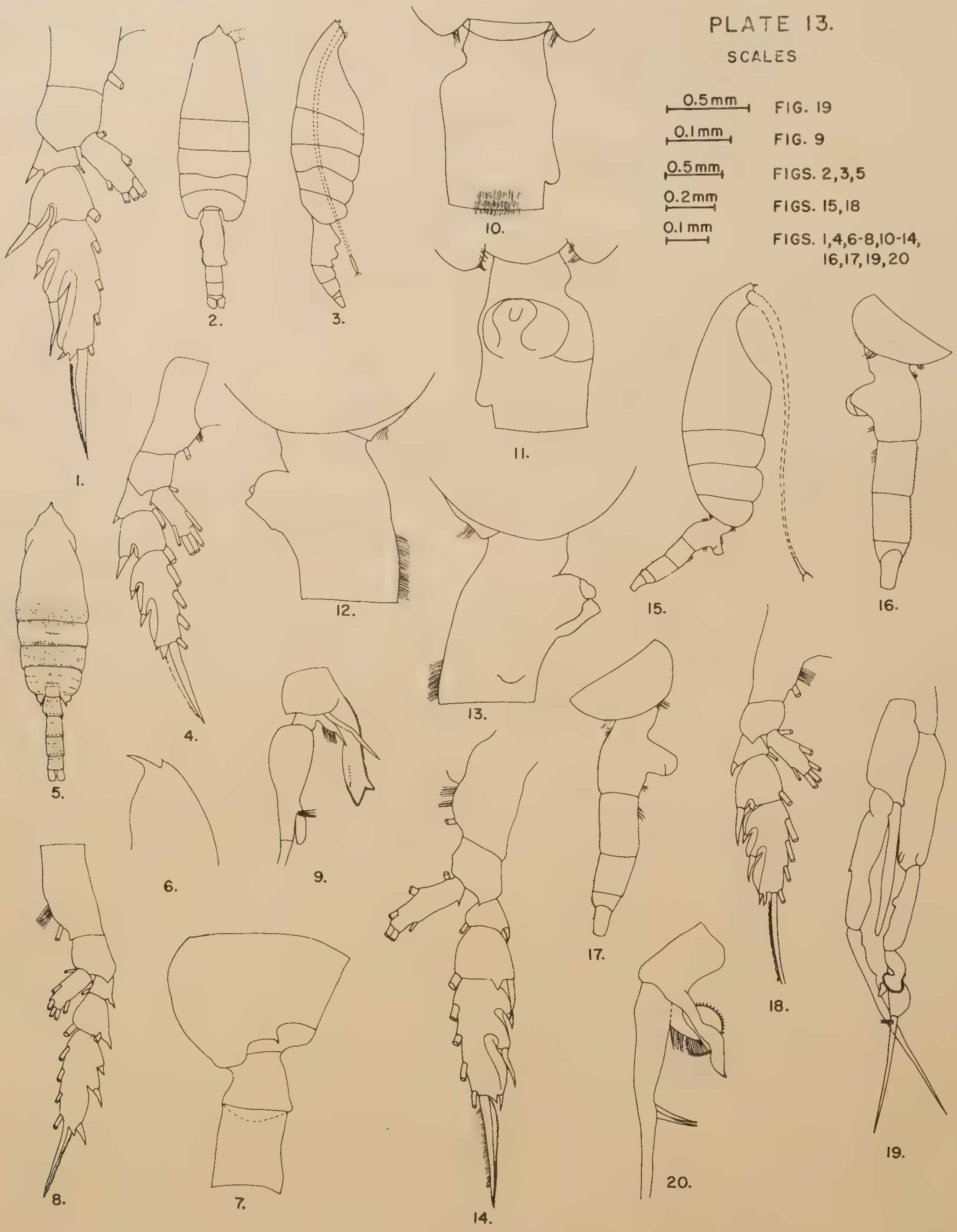


PLATE 13.
SCALES
0.5 mm FIG. 19
0.1 mm FIG. 9
0.5 mm FIGS. 2,3,5
0.2 mm FIGS. 15,18
0.1 mm FIGS. 1,4,6-8,10-14, 16,17,19,20
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.
19.
20.

PLATE 13.—(1) *Euchaeta marina,* female, second foot; (2) *E. wolfendeni,* female, dorsal view; (3) lateral view; (4) second foot; (5) male, dorsal view; (6) forehead, lateral view; (7) posterior part of thorax and first two abdominal segments, lateral view; (8) second foot; (9) terminal part of left fifth foot; (10) *E. media,* female, genital segment, dorsal view; (11) genital segment, ventral view; (12) genital segment, left side; (13) genital segment, right side; (14) second foot; (15) *E. tenuis,* female, lateral view; (16) posterior part of thorax and abdomen, left side; (17) posterior part of thorax and abdomen, right side; (18) second foot; (19) male, fifth pair of feet; (20) terminal part of left fifth foot.

al., 1955; Chiba, 1956; Honjo et al., 1957; Tanaka, 1958; Yamazi, 1958a.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	132	1 female, 2.50 mm.
Do	63	1 female, 2.52 mm.
Stranger	34	3 females, 2.24–2.38 mm.; 2 males, 2.21, 2.35 mm.
Horizon	32	1 female, 2.55 mm.; 3 males, 2.31–2.44 mm.
Satsuma	32	2 females, 2.38, 2.40 mm.; 1 male, 2.31 mm.

Remarks: The female is distinguished by the long genital segment, the right posterior margin of which is produced into a rounded knob (fig. 2). The relative lengths of the outer-edge spines on the second and third exopodal segments of the second feet (fig. 4) are also diagnostic (cf. *E. marina*, plate 13, fig. 1). The male is identified by the structure of the terminal part of the left fifth foot (fig. 9).

Euchaeta media Giesbrecht, 1888

(PLATE 13, FIGS. 10–14)

Pacific records: Vervoort, 1957. Also, Johnson, 1942; Brodsky, 1950; Tsuruta and Chiba, 1954b; Chiba, Tsuruta, and Maéda, 1955; Nagaya et al., 1955; Heinrich, 1957b; Honjo et al., 1957; Tanaka, 1958.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	63	1 female, 3.52 mm.

Remarks: The female of *E. media* is recognized by the characteristic swelling on the left side and the knob-like protrusion on the right side of the genital segment (figs. 10, 11). The middle spine on the outer edge of the third exopodal segment of the second pair of feet is elongate and the spine on the second exopodal segment reaches beyond the base of the proximal spine on the third segment (fig. 14).

Euchaeta tenuis Esterly, 1906

(PLATE 13, FIGS. 15–20)

Pacific records: Esterly, 1906; Scott, 1909; Brodsky, 1950. As *E. solida*, Esterly, 1911.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	29	4 females, 5.60–5.98 mm.; 3 males, 5.03–5.22 mm.
Do	63	1 female, 5.13 mm.; 1 male, 4.75 mm.
Do	32	present.

Remarks: The large and asymmetrical ventral protrusions (figs. 16, 17) of the female genital segment will identify this species. The outer-edge spines of the second pair of feet (fig. 18) are also diagnostic. In the male the structure of the second segment of the left fifth foot (figs. 19, 20) is characteristic. It is dilated and coarsely serrate.

Euchaeta concinna Dana, 1849

(PLATE 14, FIGS. 1–13)

Synonymy:

Euchaeta consimilis Farran, 1936, Great Barrier Reef Exped. 1928–29. Sci. Rept. 5(3): 90.

Pacific records: Scott, 1909; Farran, 1936; Mori, 1937; Dakin and Colefax, 1940; Wilson, 1950; Tanaka, 1953; Rose, 1955; Honjo et al., 1957; Heinrich, 1958b; Tanaka, 1958. As *E. consimilis;* Farran, 1936; Rose, 1955.

Vessel:	*Station*	*Occurrence*
Satsuma	32	3 females, 2.52–2.55 mm.; 1 male, 2.24 mm.

Remarks: Farran (1936) described *E. consimilis* from 4 female specimens collected near the Great Barrier Reef. He also found *E. concinna* in his collections, but this species was observed only inside the reef where it was one of the most characteristic of the copepods. According to Farran, *consimilis* differs, morphologically, from *concinna* in the form of the protrusion on the right side of the genital segment in the female (see Farran's fig. 6) and in size. As Farran pointed out, Sewell (1929) observed "a considerable degree of variation" in the form of the genital protrusion in *concinna* collected in the Indian Ocean. The latter author suggested that this variation may be correlated with egg laying which causes the protrusion to increase in size.

The size of specimens, as recorded in the literature is also variable.

Source:	*Female*	*Male*
Mori, 1937 (Japan)	3.0 mm.	
Tanaka, 1958 (Japan)	2.87–3.25 mm.	----------

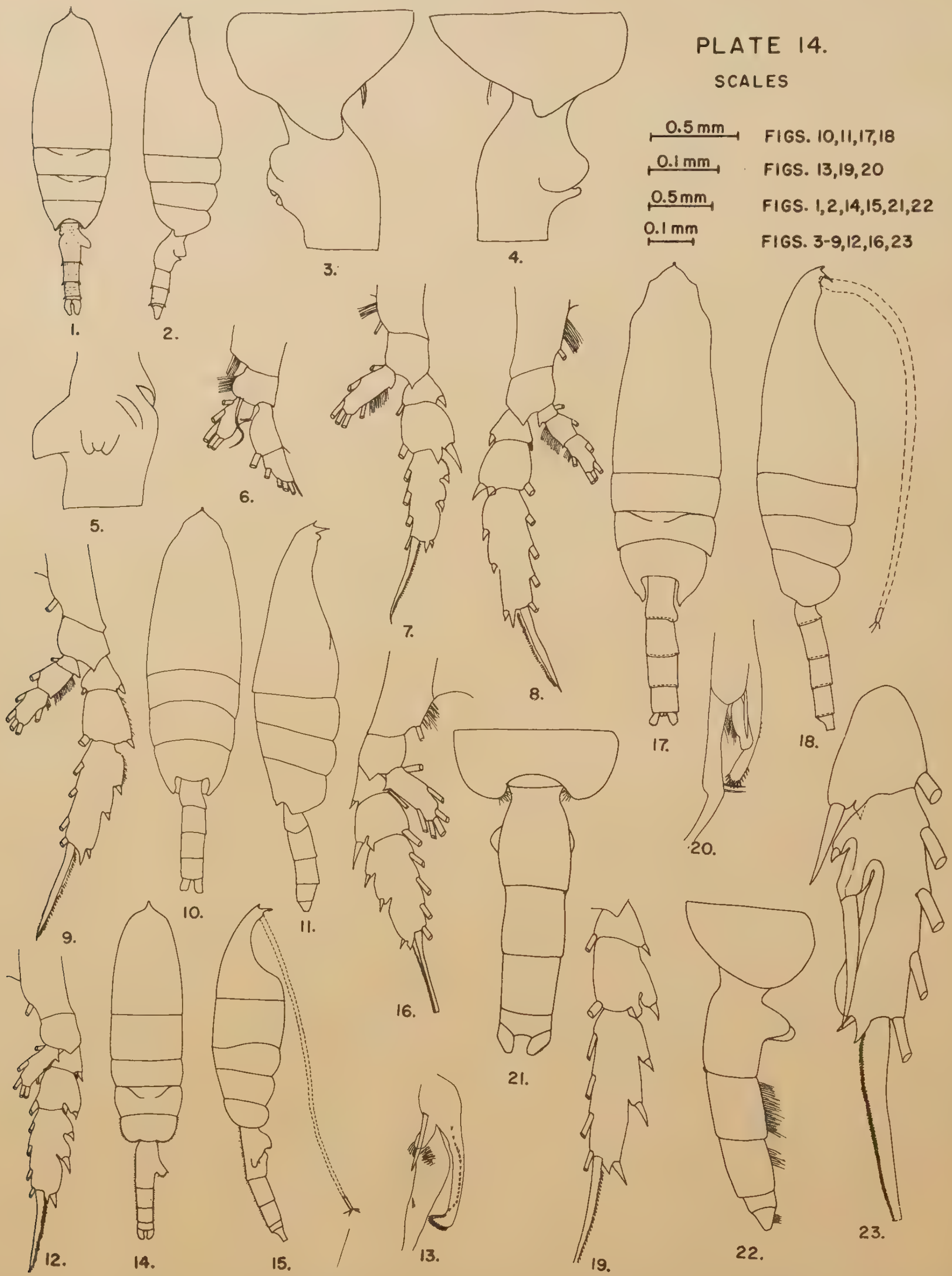


PLATE 14.
SCALES
0.5 mm FIGS. 10,11,17,18
0.1 mm FIGS. 13,19,20
0.5 mm FIGS. 1,2,14,15,21,22
0.1 mm FIGS. 3-9,12,16,23
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.
19.
20.
21.
22.
23.

PLATE 14.—(1) *Euchaeta concinna*, female, dorsal view; (2) lateral view; (3) posterior part of thorax and genital segment, left side; (4) posterior part of thorax and genital segment, right side; (5) genital segment, ventral side; (6) first foot; (7) second foot; (8) third foot; (9) fourth foot; (10) male, dorsal view; (11) lateral view; (12) second foot; (13) terminal part of left fifth foot; (14) *E. longicornis*, female, dorsal view; (15) lateral view; (16) second foot; (17) male, dorsal view; (18) lateral view; (19) exopod of second foot; (20) terminal part of left fifth foot; (21) *E. spinosa*, female, posterior part of thorax and abdomen, dorsal view; (22) lateral view; (23) second and third segments of exopod of second foot.

Vessel:	Station	Occurrence
Giesbrecht and Schmeil, 1898 (tropical Pacific)	3.3 mm.	2.75 mm.
Heinrich, 1958b (tropical Pacific)	2.5 mm.	----------
Farran, 1936 (inside Barrier Reef)	3.25–3.40 mm.	2.54–2.76 mm.
Farran, 1936 (outside Barrier Reef)	2.36–2.67 mm.	----------
Dakin and Colefax, 1940 (Australia)	3.75 mm.	2.6 mm.
Sewell, 1929 (Indian Ocean)	2.5–3.5 mm.	2.4–3.0 mm.
Wolfenden, 1905 (Indian Ocean)	2.75–3.0 mm.	----------

In view of the wide size range in both sexes and the variable nature of the genital segment in the female, it seems best to consider *E. consimilis* as a synonym of *E. concinna*.

Euchaeta longicornis Giesbrecht, 1888

(PLATE 14, FIGS. 14–20)

Pacific records: Scott, 1909; Farran, 1929; 1936; Mori, 1937; Wilson, 1950; Honjo, 1952; Nakai, 1952; Tanaka, 1953; Anraku, 1954b; Chiba, Tsuruta, and Maéda, 1955; Nagaya et al., 1955; Honjo et al., 1957; Tanaka, 1958.

Vessel:	Station	Occurrence
Hugh M. Smith	94	3 females, 2.88 mm.
Do	132	8 females, 2.65–2.92 mm.; 1 male, 2.65 mm.

Remarks: The female genital segment has a large protrusion on the right side from which arises a smaller spine-like process.

Wilson (1950) described the male sex of this species. I have compared my single male specimen (except the body, which was destroyed in dissection) to one identified by G. O. Sars and loaned to me by the U.S. National Museum. The two are unispecific. In the Museum specimen a small spine is present on the superior-lateral margins of the fifth thoracic segment as is also found on the male of *E. wolfendeni* (see plate 13, fig. 7). I probably overlooked these spines in my specimen and therefore they are not shown in the figure given of the male (fig. 18).

Euchaeta spinosa Giesbrecht, 1892

(PLATE 14, FIGS. 21–23)

Pacific records: Esterly, 1905; Johnson, 1942; Brodsky, 1950; Wilson, 1950; Tanaka, 1953; 1958. As male of *Undeuchaeta major;* Esterly, 1905.

Vessel:	Station	Occurrence
Hugh M. Smith	29	1 female, 6.94 mm.

Remarks: The ventral projections of the genital segment (fig. 22) are visible in dorsal view. The middle spine on the outer margin of the third exopodal segment of the second feet is greatly elongate, and the spine on the second exopodal segment surpasses the tip of the first spine on the third segment (fig. 23).

Family PHAENNIDAE

Phaenna spinifera Claus, 1863

(PLATE 15, FIG. 1)

Pacific records: Scott, 1909; Farran, 1929; Mori, 1937; Wilson, 1942; 1950; Tanaka, 1953; Anraku, 1954b; 1954c; Tsuruta and Chiba, 1954b; Chiba, Tsuruta, and Maéda, 1955; Motoda and Anraku, 1955; Nagaya et al., 1955; Chiba, 1956; Honjo et al., 1957; Yamazi, 1958a. As *Onchocalanus nudipes;* Wilson, 1942.

Vessel:	Station	Occurrence
Hugh M. Smith	94	present.
Do	132	3 females, 1.87–1.90 mm.
Do	31	1 female, 1.60 mm.
Do	63	present.
Orsom	10	1 female, 1.87 mm.
Horizon	32	present.

Remarks: The globular thorax, small abdomen, and lack of fifth feet (in the female) make this species easily recognized. Vervoort (1950) placed Wilson's *Onchocalanus nudipes* in synonymy with *Phaenna spinifera.*

Xanthocalanus dilatus n. sp.

(PLATE 15, FIGS. 2–11)

Vessel:	Station	Occurrence
Hugh M. Smith	144	2 females, 1.56, 1.60 mm.

Description: The head and first thoracic segment and fourth and fifth thoracic segments are separate (figs. 2, 3). The posterior lateral margins of the first thoracic segment are dis-

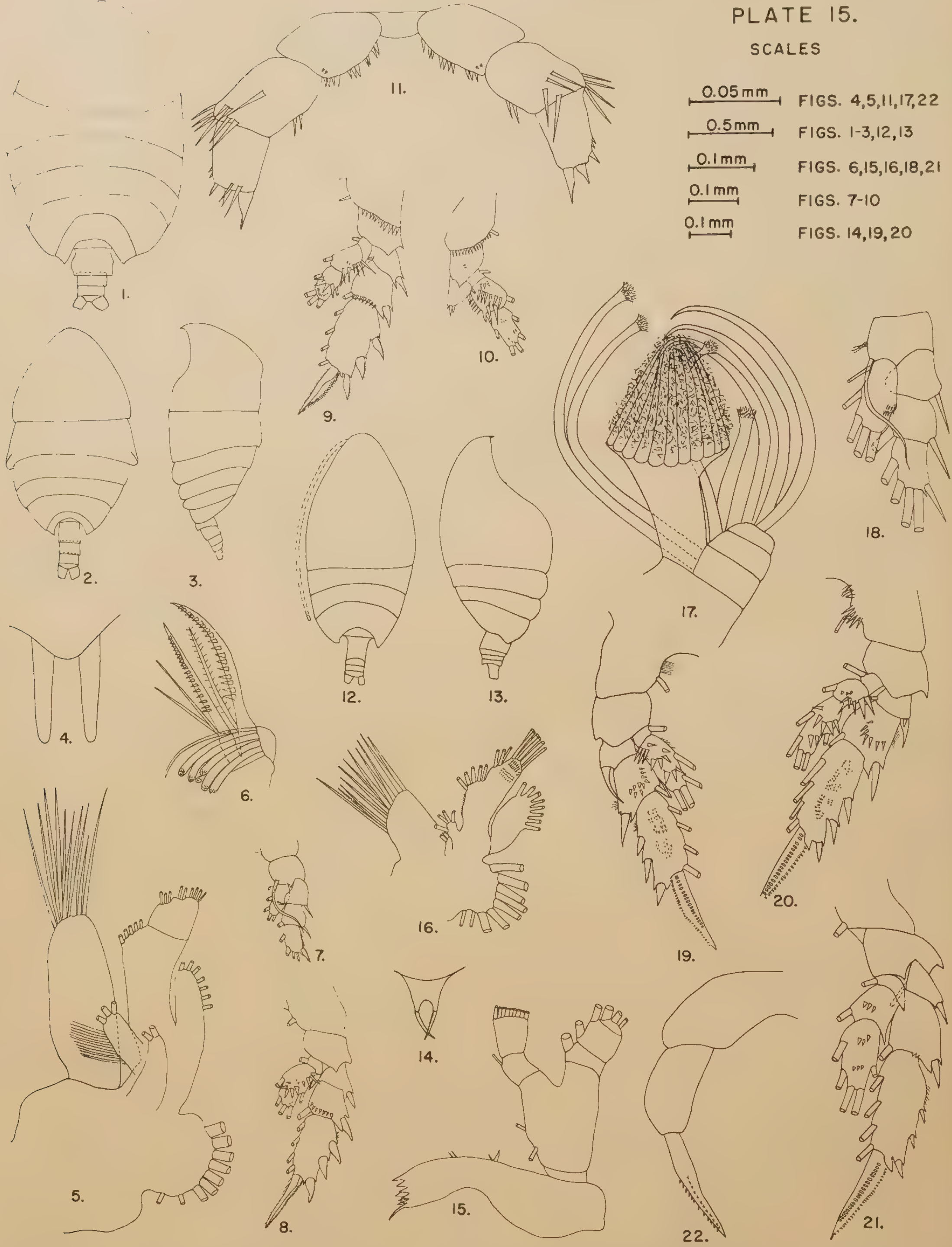


PLATE 15.
SCALES
0.05 mm FIGS. 4,5,11,17,22
0.5 mm FIGS. 1-3,12,13
0.1 mm FIGS. 6,15,16,18,21
0.1 mm FIGS. 7-10
0.1 mm FIGS. 14,19,20
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.
19.
20.
21.
22.

Plate 15.—(1) *Phaenna spinifera*, female, dorsal view; (2) *Xanthocalanus dilatus* n.sp., female, dorsal view; (3) lateral view; (4) rostrum; (5) first maxilla, (6) terminal part of second maxilla; (7) first foot; (8) second foot; (9) third foot; (10) fourth foot (distal two segments of exopod missing); (11) fifth pair of feet (figs. 2–6 and 11 of holotype, figs. 7–10 of paratype); (12) *Amallophora smithae* n. sp., female, dorsal view; (13) lateral view; (14) rostrum; (15) mandible; (16) first maxilla; (17) terminal part of second maxilla; (18) first foot; (19) second foot; (20) third foot; (21) fourth foot; (22) fifth foot (figs. 12–22 of holotype).

ded and there is a distinct dilation on the
rsal surface of the head. The rostrum is
aight and club-like (fig. 4).

The first antennae of both specimens are
ken off near the proximal end. Although
newhat mutilated, the second antennae ap-
ir to have 1 seta on the first segment of the
lopod. The second segment of the endopod
s 14 setae on the distal margin (8 on the in-
lobe and 6 on the outer lobe). The exopod
s a total of 6 setae but some may be missing
m the various segments.

The mandible has 3 setae on the basipod, 11
ae on the endopod and 6 on the exopod.

The first maxilla (fig. 5) has the following
mber of setae: 9 on the external lobe, 7 on
exopod, 9 on the endopod, 5 on the second
sal segment, 2 on the second internal lobe and
n the third internal lobe.

The terminal part of the second maxilla (fig.
has 6 sensory organs and 1 worm-like ap-
ndage.

The exopods of the first 4 pairs of feet are
segmented (figs. 7–10), although the second
d third exopodal segments of the fourth pair
e broken off. The endopod of the first foot
nsists of 1 segment, of the second foot of 2
gments and of the third and fourth feet of 3
gments. The endopodal segments of the sec-
d and third feet have numerous spines aris-
g from their posterior surfaces. A row of
ines is present at the junction of the first and
cond basipodal segments, on the posterior
le, of the third and fourth feet. The fifth
ot (fig. 11) consists of 3 segments, all of
hich are furnished with either marginal or
rface spines.

Remarks: This species differs from other de-
ribed *Xanthocalanus* in (1) the dilations of
e dorsal surface of the head and lateral mar-
ns of the first thoracic segment, (2) the
ines on the basipodal segments of the third
d fourth feet, and (3) the details of the fifth
ir of feet. The fifth pair of feet closely re-
mble those of *X. agilis* Giesbrecht but *agilis*
cks the characteristic dilations of the head
d first thoracic segment of the present spe-
es. In addition, *X. agilis* is a larger species
.40 mm.). The presence of spines on the
sipodal segments may also be found in other
species of *Xanthocalanus*. Figures of these segments are available for only a few species.

The name proposed for this species is derived from the Latin word "dilato" and refers to the characteristic protrusions on the head and first thoracic segment. The holotype (U.S.N.M. No. 104, 420) and 1 paratype (No. 104, 421) have been deposited in the U.S. National Museum.

Amallophora smithae n. sp.

(PLATE 15, FIGS. 12–22)

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	144	1 female, 1.40 mm.

Description: The head and first thoracic segments and the fourth and fifth thoracic segments are fused (fig. 12). In lateral view the posterior margin of the cephalothorax has a small indentation (fig. 13).

The first antennae are short and do not reach the end of the cephalothorax. Each antenna consists of 23 segments.

The endopod of the second antenna is slightly less than three-fourths the length of the exopod. Endopodal segment 1 has 2 setae. Segment 2 has 8 setae on the inner lobe and 7 setae on the outer lobe. The exopod has 8 setae all of which are densely plumose.

The basal segment of the mandibular palpus has 2 setae (fig. 15). There are 9 setae on the distal segment of the endopod and 1 seta on the proximal segment. The exopod has a total of 6 setae.

The first maxilla (fig. 16) has the following number of setae: 11 on the first inner lobe, 2 on the second inner lobe, 4 on the third inner lobe, 5 on the second basal segment, 9 on the endopod, 8 on the exopod and 9 on the external lobe. Two groups of small spines are present on the surface of the endopod.

The terminal part of the second maxilla (fig. 17) has 1 enlarged sensory organ, 4 smaller sensory organs and 3 worm-like appendages.

The first and second basal segments of the maxilliped have 7 and 5 setae, respectively. The 5 endopodal segments have the following number of setae: 4, 4, 3, 3 (plus 1 external seta), and 4.

The first pair of feet have 3-segmented exopods and 1-segmented endopods (fig. 18). The second pair of feet have exopods composed of 3 segments and endopods of 2 segments while the succeeding 2 pairs of feet each have 3-segmented exopods and endopods (figs. 19–21). The terminal spine of the second, third, and fourth pair of feet is characterized by an outer serrate margin and an inner row of small perforations. The endopods of the second and third feet have large spines arising from their surfaces. Numerous smaller spines are present on the 2 distal exopodal segments of the second and third feet. The fourth feet have a reduced number of spines.

The fifth feet (fig. 22) are small and consist of 2 segments. There is a stout and finely toothed spine arising from the distal segment.

Remarks: This species is closely related to *A. vorax* (Esterly, 1911). It differs from Esterly's species in the segmentation of the cephalothorax, cephalothorax-abdomen ratio, and the structure of the fifth feet. The fourth and fifth thoracic segments are separate in *A. vorax* but fused in *A. smithae.* Davis (1949) also reported that these segments in his specimen of *A. vorax* were fused. The cephalothorax is 6½ times longer than the abdomen in *A. vorax* according to Esterly; in the present species it is approximately 4 times the length of the abdomen. Davis stated that the abdomen of his specimen was longer than that reported by Esterly. In *A. vorax* there are two spines on the distal segment of the fifth feet. In *A. smithae* there is one robust spine.

Vervoort (1957) has discussed the genus *Amallophora* and pointed out differences between it and the genus *Xanthocalanus.* The structures of the maxillae and fifth feet appear to exclude the present species from the genus *Xanthocalanus* although the articulated rostral filaments are unlike those found in *Amallophora.* If Brodsky (1950) is correct in assigning Esterly's species (described as *Scolecithrix vorax*) to the genus *Amallothrix* then perhaps the present species should also be placed in this genus. Until the *Xanthocalanus–Amallothrix–Amallophora* complex is revised, I am referring the present species to the genus *Amallophora.*

The species is named for the research vessel *Hugh M. Smith.* The holotype is deposited in the U.S. National Museum (No. 104, 422).

Family SCOLECITHRICIDAE

Scolecithrix danae (Lubbock, 1856)

Pacific records: Esterly, 1905; Scott, 1909; Farran, 1929; Yamada, 1933; Farran, 1936; Mori, 1937; Dakin and Colefax, 1940; Johnson, 1942; Mori, 1942; Wilson, 1942; 1950; Anraku, 1952; Honjo, 1952; Nakai, 1952; Tanaka, 1953; Anraku, 1954b; Johnson, 1954; Tsuruta and Chiba, 1954b; Chiba, Tsuruta, and Maéda, 1955; Hida and King, 1955; Motoda and Anraku, 1955; Nagaya et al., 1955; Chiba, 1956; Honjo et al., 1957; Heinrich, 1958a; Yamazi, 1958a.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	132	present.
Do	144	present.
Do	153	present.
Do	178	present.
Do	30	present.
Do	31	3 females, 2.04–2.14 mm.
Do	29	3 females, 2.01–2.04 mm.
Do	63	4 females, 2.04–2.14; 3 males, 2.07–2.21 mm.
Stranger	34	2 females, 2.00, 2.04 mm.
Orsom	10	2 females, 2.01, 2.11; 1 male, 1.97 mm.
Horizon	32	3 females, 2.04; 2 males, 2.04, 2.11 mm.
Satsuma	32	2 females, 1.90, 2.00 mm.

Remarks: The posteriorly directed ventral protrusion on the female genital segment and the structure of the fifth feet of the male serve to identify this species. Figures of both these characters are given in Rose, 1933.

Scolecithrix bradyi Giesbrecht, 1888

(Plate 16, figs. 1–5)

Pacific records: Esterly, 1905; Farran, 1929; 1936. As *Scolecithricella bradyi;* Scott, 1909; Mori, 1937; 1942; Wilson, 1942; 1950; Honjo, 1952; Tanaka, 1953; Chiba, Tsuruta, and Maéda, 1955; Motoda and Anraku, 1955; Nagaya et al., 1955; Chiba, 1956; Honjo et al., 1957.

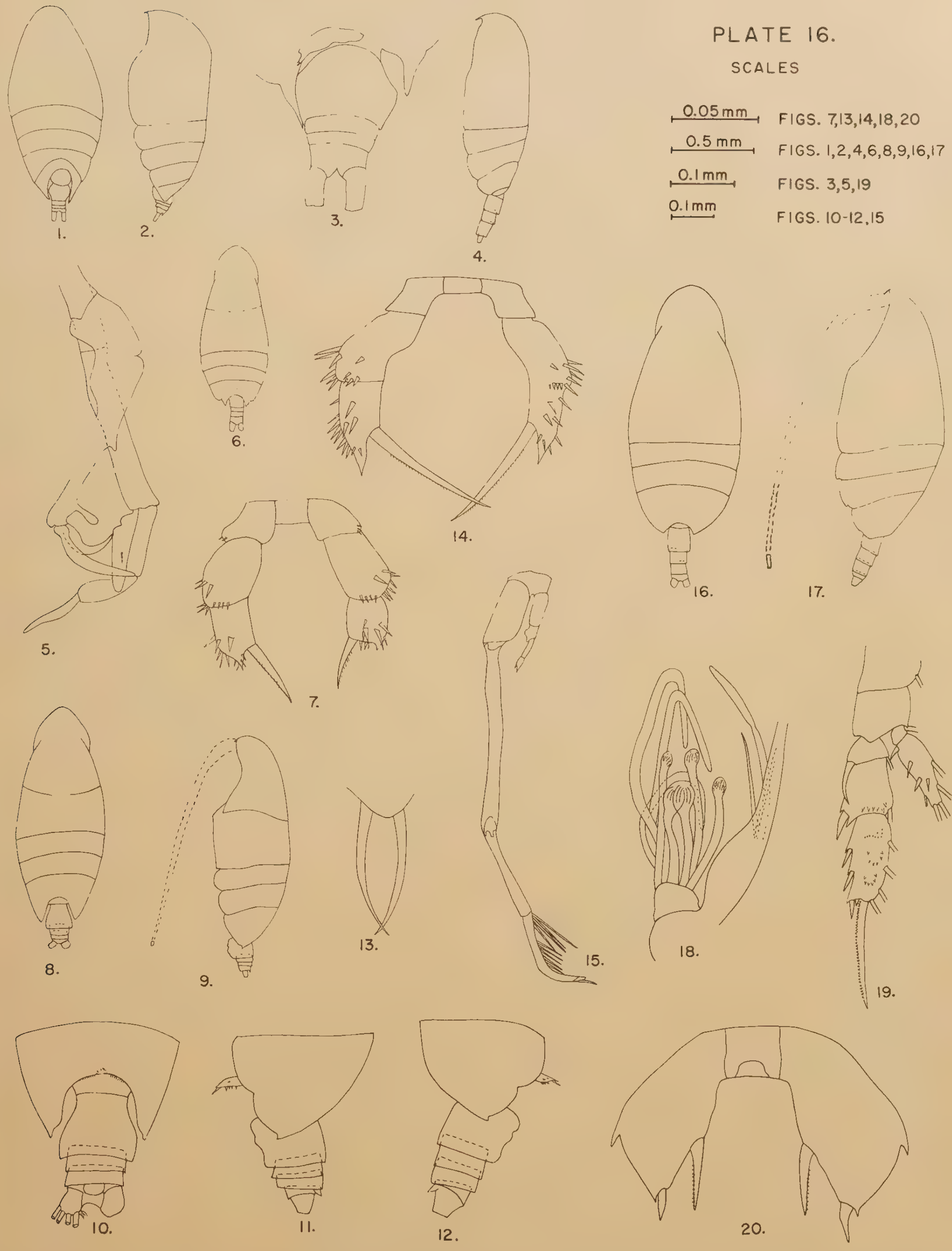


PLATE 16.
SCALES
0.05 mm FIGS. 7,13,14,18,20
0.5 mm FIGS. 1,2,4,6,8,9,16,17
0.1 mm FIGS. 3,5,19
0.1 mm FIGS. 10-12,15
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.
19.
20.

PLATE 16.—(1) *Scolecithrix bradyi*, female, dorsal view; (2) lateral view; (3) posterior part of thorax and bdomen, ventral view; (4) male, lateral view; (5) fifth pair of feet; (6) *Scolecithricella ctenopus*, female, juvenile, orsal view; (7) fifth pair of feet; (8) adult, dorsal view; (9) lateral view; (10) posterior part of thorax and bdomen, dorsal view; (11) left side; (12) right side; (13) rostrum; (14) fifth pair of feet; (15) male, fifth pair f feet; (16) *S. abyssalis*, female, dorsal view; (17) lateral view; (18) terminal part of second maxilla; (19) second foot; (20) fifth pair of feet.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	94	11 females, 1.36–1.41; 2 males, 1.51, 1.56 mm.
Do	132	4 females, 1.33–1.36 mm.
Do	144	present.
Do	178	present.
Do	31	present.

Remarks: The asymmetrical posterior thoracic margins, the right one of which extends beyond the genital segment (fig. 1), serve to identify the female of this species. The male is recognized by the structure of the fifth feet (fig. 5).

Scolecithricella ctenopus (Giesbrecht, 1888)

(Plate 16, figs. 6–15)

Synonymy:

Scolecithrix ctenopus Giesbrecht, 1888, Atti Acc. Lincei Rend., ser. 4, 4 sem. 2: 338.

Scolecithricella ctenopus Sewell, 1929, Mem. Ind. Mus., 10: 212.

Scolecithrix longicornis T. Scott, 1894, Trans. Linn. Soc., Zool., 6: 50.

Scolecithricella spinipedata Mori, 1937, The pelagic Copepoda from the neighbouring waters of Japan, p. 53.

Pacific records: Scott, 1909; Farran, 1936; Tanaka, 1953.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	94	1 juvenile female, 1.28 mm.
Do	178	2 females, 1.49, 1.53; 1 male, 1.54 mm.
Stranger	34	1 female, 1.46; 1 male, 1.46 mm.
Orsom	10	1 female, 1.48 mm.

Remarks: Farran (1936) found two females which differed in size, segmentation of thorax and structure of fifth feet. He also reviewed the records and descriptions of *S. longicornis* (Scott, 1894) and considered it a synonym of *S. ctenopus*.

The present female specimens also fall into two size groups, the smaller of which is very similar to Farran's small specimen. The head and thorax in this form are separated by a fine line (in Farran's specimen they were fused) and a faint line is also seen to separate the fourth and fifth thoracic segments (fig. 6). Although the fifth feet are fairly well differentiated, the genital segment is undeveloped in this small specimen. In the larger form (figs. 8–14) the head and first thoracic segment are incompletely fused and the fourth and fifth thoracic segments are completely fused. The genital segment is well developed as are the fifth feet.

Although it is slightly larger, Mori's *S. spinipedata,* is, in my opinion, a synonym of *S. ctenopus.*

Scolecithricella abyssalis (Giesbrecht, 1888)

(Plate 16, figs. 16–20)

Pacific records: Scott, 1909; Mori, 1937; Tanaka, 1937; Wilson, 1942; 1950; Anraku, 1952; Tanaka, 1953; Brodsky, 1955; Chiba, Tsuruta, and Maéda, 1955; Nagaya et al., 1955; Chiba, 1956.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	94	6 females, 1.87–1.90 mm.
Do	144	1 female, 1.74 mm.
Do	29	1 female, 2.21 mm.
Do	63	1 female, 1.87 mm.

Remarks: Some variation was noted in the structure of the fifth feet of this species. Several specimens did not have the small spine-like protrusion near the terminal spine as shown in the fifth feet figured here (fig. 20).

Scolecithricella vittata (Giesbrecht, 1892)

(Plate 17, figs. 1–8)

Pacific records: Farran, 1936; Wilson, 1950; Tanaka, 1953.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	94	2 females, 1.66 mm.

Remarks: As in the preceding species, variation was noted in the fifth feet of this species. The terminal seta in one specimen was approximately twice the length of the proximal one (fig. 8) while in the other specimen it was somewhat shorter (fig. 4).

Scolecithricella tenuiserrata (Giesbrecht, 1892)

(Plate 17, figs. 9–21; plate 18, fig. 1)

Pacific records: Farran, 1936; Tanaka, 1953.

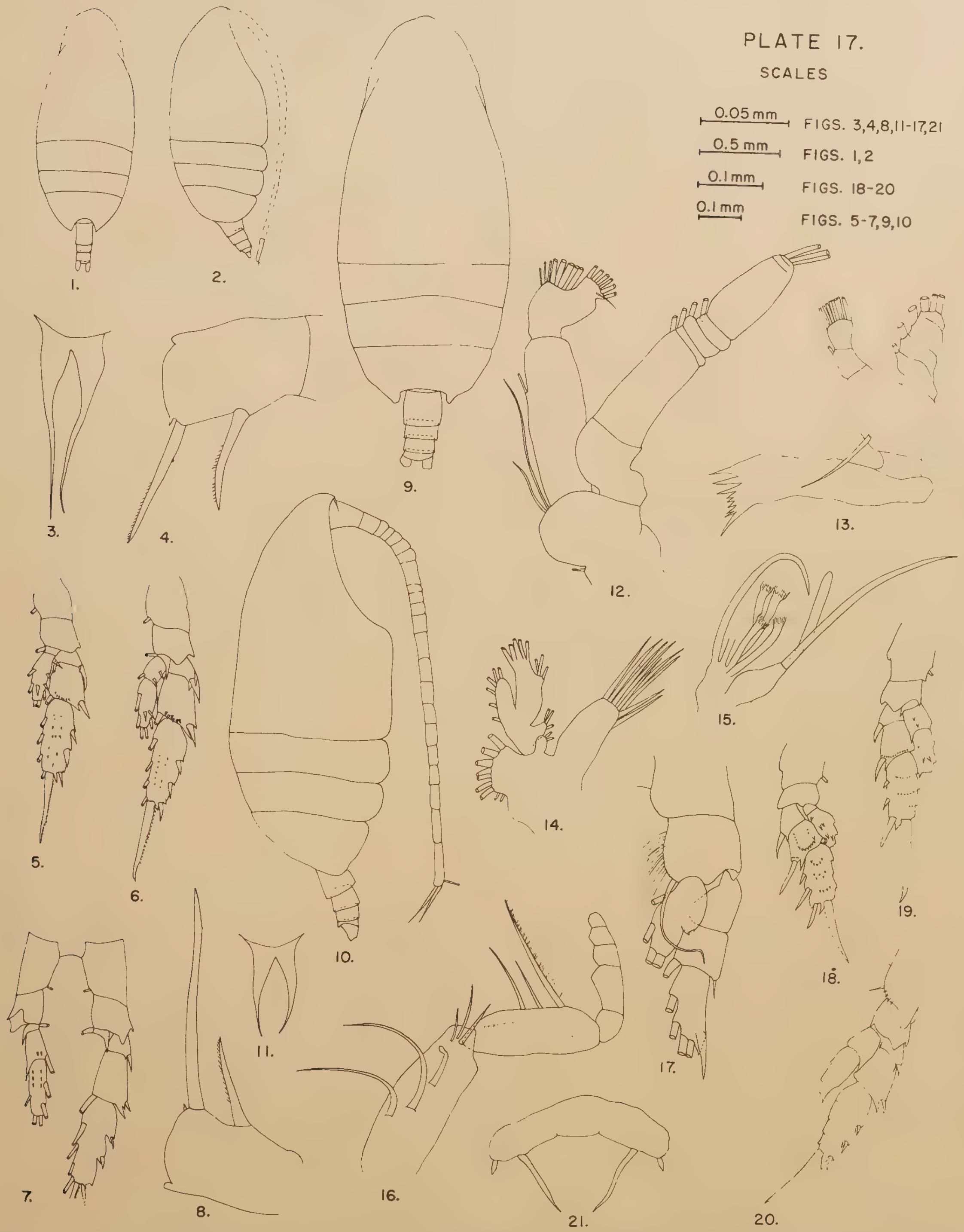


PLATE 17.
SCALES
0.05 mm FIGS. 3,4,8,11-17,21
0.5 mm FIGS. 1,2
0.1 mm FIGS. 18-20
0.1 mm FIGS. 5-7,9,10
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.
19.
20.
21.

PLATE 17.—(1) *Scolecithricella vittata,* female, dorsal view; (2) lateral view; (3) rostrum; (4) fifth foot; (5) second foot; (6) third foot; (7) fourth pair of feet (one exopod and one endopod missing); (8) fifth foot; (9) *S. tenuiserrata,* female, dorsal view; (10) lateral view; (11) rostrum; (12) second antenna; (13) mandible; (14) first maxilla; (15) terminal part of second maxilla; (16) maxilliped (setae on endopod not shown); (17) first foot; (18) second foot (setae not shown); (19) third foot (setae not shown); (20) fourth foot (setae not shown); (21) fifth pair of feet.

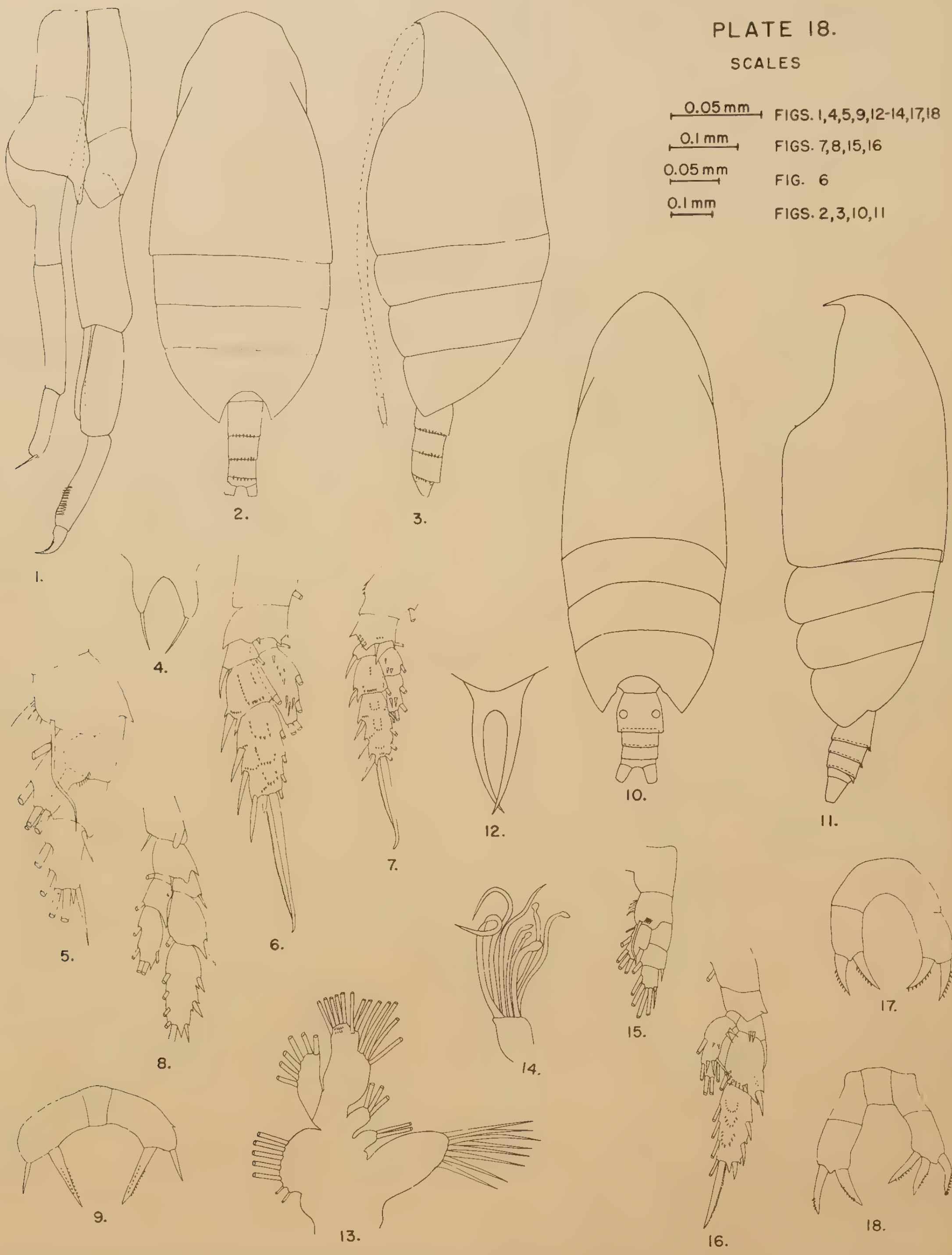


PLATE 18.
SCALES
0.05 mm FIGS. 1,4,5,9,12-14,17,18
0.1 mm FIGS. 7,8,15,16
0.05 mm FIG. 6
0.1 mm FIGS. 2,3,10,11
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.

PLATE 18.—(1) *Scolecithricella tenuiserrata*, male, fifth pair of feet; (2) *S. marginata*, female, dorsal view (3) lateral view; (4) rostrum; (5) first foot; (6) second foot; (7) third foot; (8) fourth foot; (9) fifth pair o feet; (10) *Scolecithricella tropica* n. sp., female, dorsal view; (11) lateral view; (12) rostrum; (13) first maxilla (14) terminal part of second maxilla; (15) first foot; (16) second foot; (17) fifth pair of feet; (18) fifth pai of feet, abnormal (figs. 10–18 of paratype).

ssel:	*Station*	*Occurrence*
Hugh M. Smith	144	1 female, 1.08 mm.; 1 male, 1.17 mm.
Do	178	4 females, 1.05–1.10 mm.; 4 males, 1.0–1.27 mm.
Do	31	present.
Stranger	34	3 females, 1.02–1.10 mm.

Remarks: Because of the difficulty encoun- red in identifying this species, I have included veral figures of the female and a figure of e fifth feet of a specimen that I consider to the male of this species. Giesbrecht and hmeil (1898) stated that the second basal gment of the first maxilla of the female has setae. The present specimens have 3 setae this segment. Although these authors indi- ted that the male of this species is question- le, they gave the length as 1.45 mm. as com- red to 1.15 mm. for the female. The present ales are also larger than the females.

Scolecithricella marginata (Giesbrecht, 1888)

(PLATE 18, FIGS. 2–9)

Pacific records: Scott, 1909; Wilson, 1942.

ssel:	*Station*	*Occurrence*
Hugh M. Smith	144	2 females, 1.05 mm.
Do	178	2 females, 1.00, 1.02 mm.

Remarks: The small size and fifth feet (fig. serve to identify this species.

Scolecithricella tropica n. sp.

(PLATE 18, FIGS. 10–18)

ssel:	*Station*	*Occurrence*
Hugh M. Smith	94	4 females, 1.22–1.30 mm.
Do	132	5 females, 1.15–1.27 mm.
Do	178	2 females, 1.13, 1.14 mm.

Description: Of the 11 specimens of this ecies examined, none was intact. The fol- wing description is based, therefore, on sev- ral specimens and even with these a discus- on of certain appendages will not be possible.

The cephalothorax is considerably longer an the abdomen, the ratio of these two body rts is approximately 4.4: 1.0 (figs. 10, 11). The posterior thoracic border has a well-defined indentation at a point just anterior to the apex. The genital segment is longer than the combined lengths of the next 2 segments. The rostral filaments are long and apparently not articulated to the base (fig. 12).

The first maxilla (fig. 13) has the following number of setae: 2 on the second inner lobe, 3 on the third inner lobe, 5 on the second basal segment, 8 on the endopod, and 6 on the exopod.

The terminal portion of the second maxilla (fig. 14) has 5 sensory and 3 worm-like appendages.

The first pair of feet (fig. 15) has a 3-segmented exopod and 1-segmented endopod. A group of small spines is present on the second basal segment near the distal margin. The exopod of the second pair of feet consists of 3 segments and the endopod of 2 segments (fig. 16). Two spines are present on the surface of the first exopodal segment, a group of large and small spines on the second segment and three groups of spines on the third exopodal segment. Five large and 2 small spines are present on the second endopodal segment.

As in certain other species of *Scolecithricella*, the fifth feet are variable. Most of the specimens examined have 2, approximately equal, terminal spines (fig. 17) but at least 2 specimens were observed to have 3 on one side and 2 on the other (fig. 18).

This species is distinguished from other species of *Scolecithricella* by the indentation on the posterior thoracic margin and the structure of the fifth feet.

Remarks: An undissected female from Station 94 was selected as the holotype (U.S.N.M. No. 104, 416). This specimen and 6 paratypes (Nos. 104, 417–104, 419) have been deposited in the U.S. National Museum.

Scolecithricella sp.

(PLATE 19, FIGS. 1–5)

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	144	2 males, 1.20, 1.22 mm.

Remarks: Two male specimens which are apparently referable to the genus *Scolecithri-*

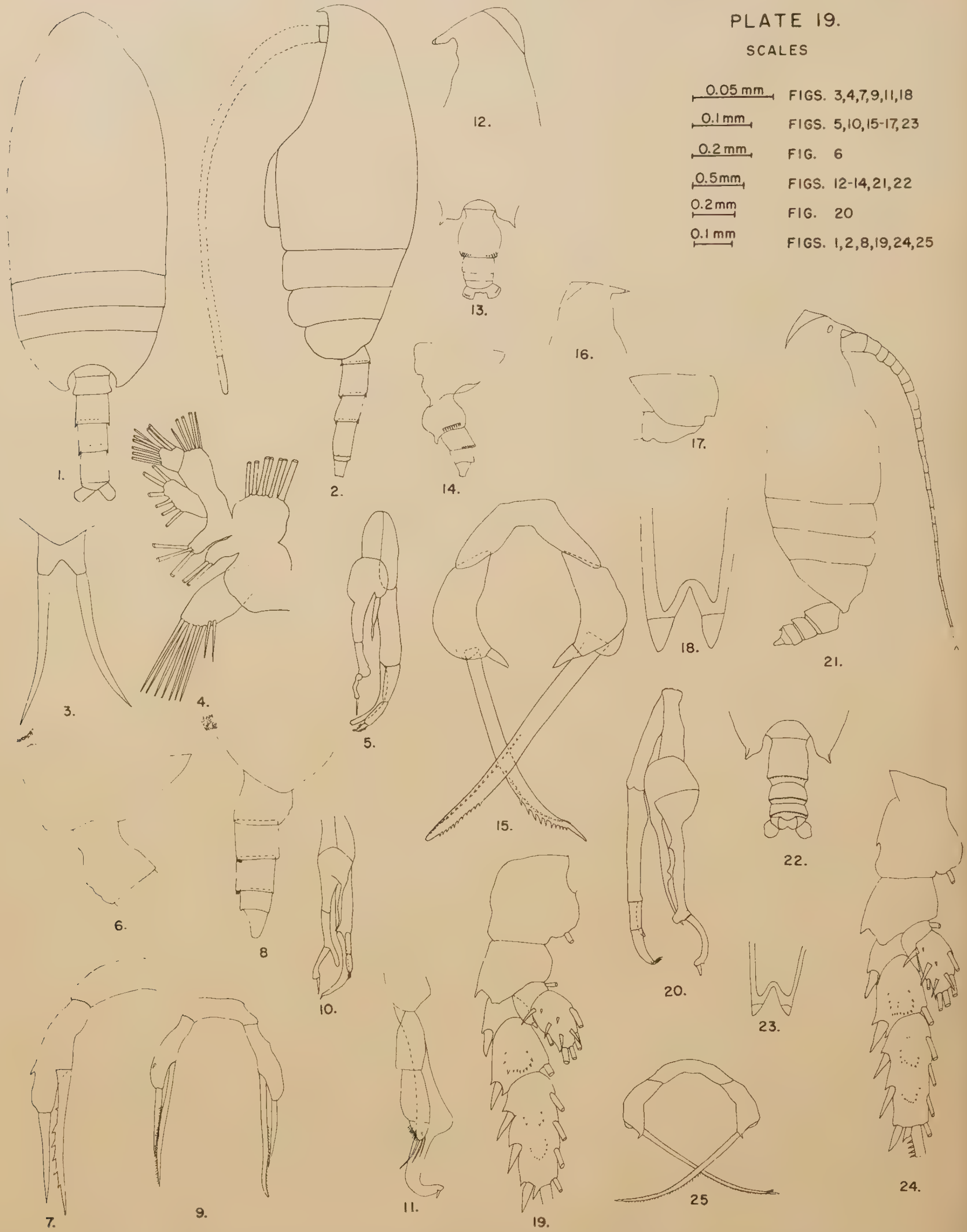


PLATE 19.
SCALES
0.05 mm FIGS. 3,4,7,9,11,18
0.1 mm FIGS. 5,10,15-17,23
0.2 mm FIG. 6
0.5 mm FIGS. 12-14,21,22
0.2 mm FIG. 20
0.1 mm FIGS. 1,2,8,19,24,25
1.
2.
3.
4.
5.
6.
7.
8
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.
19.
20.
21.
22.
23.
24.
25

PLATE 19.—(1) *Scolecithricella sp.*, male, dorsal view; (2) lateral view; (3) rostrum; (4) first maxill
(5) fifth pair of feet; (6) *Scaphocalanus echinatus*, female, posterior part of thorax and genital segment; (7) fif
foot; (8) *S. longifurca*, female, posterior part of thorax and abdomen, lateral view; (9) fifth pair of feet; (10) ma
fifth pair of feet; (11) left fifth foot; (12) *Scottocalanus securifrons*, female, forehead, lateral view; (13) abdom
dorsal view; (14) posterior part of thorax and abdomen, lateral view; (15) fifth pair of feet; (16) *S. farrani*, ma
forehead, lateral view; (17) posterior part of thorax and genital segment, lateral view; (18) rostrum; (19) seco
foot; (20) fifth pair of feet; (21) *S. sedatus*, female, lateral view; (22) abdomen, dorsal view; (23) rostru
(24) second foot; (25) fifth pair of feet.

were found in the above sample. As the es of several described females, including preceding species, are not known, I hesitate escribe the present species as new.

Scaphocalanus echinatus (Farran, 1905)

(PLATE 19, FIGS. 6, 7)

acific records: Farran, 1929, 1936; Mori, 1937; son, 1950; Honjo, 1952; Tanaka, 1953; Tsuruta and ba, 1954a; Chiba, 1956; Honjo et al., 1957.

el:	Station	Occurrence
Hugh M. Smith	63	1 female, 2.00 mm.

emarks: *S. echinatus* resembles *S. longi-* *a* but the inner edge setae on the fifth feet he former species are coarsely toothed (fig.

Scaphocalanus longifurca (Giesbrecht, 1888)

(PLATE 19, FIGS. 8–11)

cific records: Tanaka, 1953. As *Scolecithricella ifurca*, Scott, 1909. As ?*Scaphocalanus gracili- la*, Tanaka, 1937.

el:	Station	Occurrence
Hugh M. Smith	94	1 male, 1.53 mm.
Do	29	2 females, 1.87, 1.94 mm.
Do	63	1 female, 1.94 mm.

emarks: The similarity of this species to *ubbrevicornis* has been pointed out by Far- (1929) and Vervoort (1951). The latter hor has indicated that Tanaka's *S. gracili- la* (male) is identical to a male doubtfully rred by Rose (1942) to *S. dentata*. Ver- t (1951) suggests that these two males may he male of *S. longifurca*. I, too, have found ale specimen which I am tentatively refer- to *S. longifurca* rather than to *S. subbre- rnis*, as figured by Vervoort, because of the ll size of the present specimen (1.53). Ver- t's specimens measured 2.19 mm. and Tan- 's single specimen was 1.75 mm. The former author has also suggested (1957) that Wilson's (1950) records of *S. subbrevicornis* are probably referable to *S. longifurca*.

Scottocalanus securifrons (T. Scott, 1894)

(PLATE 19, FIGS. 12–15)

Pacific records: Scott, 1909; Farran, 1929; Tanaka, 1937; Brodsky, 1950; Wilson, 1950; Tanaka, 1953; Hida and King, 1955; Heinrich, 1958b.

Vessel:	Station	Occurrence
Horizon	32	1 female, 4.08 mm.

Remarks: The ventral surface of the genital segment is produced posteriorly and partly overlaps the following segment (fig. 14). The spine on the left fifth foot is thicker than that on the right (fig. 15). These two characters will identify the female of this species. No male has been found in the present samples.

Scottocalanus farrani A. Scott, 1909

(PLATE 19, FIGS. 16–20)

Pacific records: Scott, 1909; Wilson, 1950.

Vessel:	Station	Occurrence
Hugh M. Smith	29	1 male, 3.50 mm.

Remarks: The structure of the fifth pair of feet particularly the relative lengths of the exo- and endopods and the presence of a tooth-like process on the second basal segment of the right foot will identify the male of this species. No females were found.

Scottocalanus sedatus Farran, 1936

(PLATE 19, FIGS. 21–25)

Pacific records: Farran, 1936.

Vessel:	Station	Occurrence
Hugh M. Smith	29	1 female, 3.40 mm.
Orsom	10	1 female, 3.30 mm.

Remarks: This species is distinguished by the long setae and small, outwardly directed spines on the terminal segments of the fifth pair of feet (fig. 25).

Family TEMORIDAE

Temoropia mayumbaensis T. Scott, 1894

(PLATE 20, FIGS. 1–12)

cific records: Scott, 1909; Farran, 1929; 1936; on, 1942; Heinrich, 1957b.

Vessel:	Station	Occurrence
Hugh M. Smith	94	6 females, 0.94–0.99; 3 males, 0.88–0.92 mm.
Orsom	10	2 females, 0.98 mm.

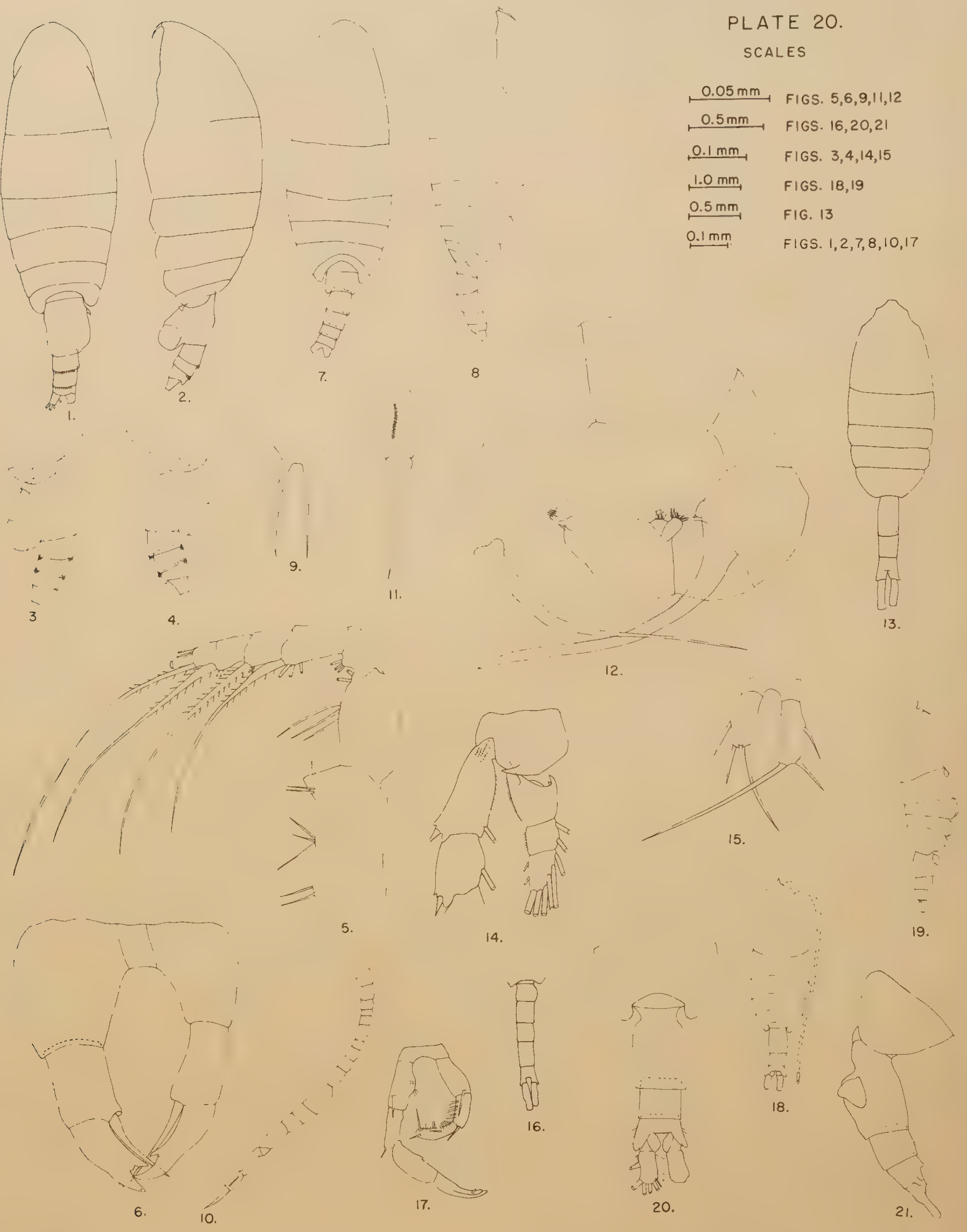


PLATE 20.
SCALES
0.05 mm FIGS. 5,6,9,11,12
0.5 mm FIGS. 16,20,21
0.1 mm FIGS. 3,4,14,15
1.0 mm FIGS. 18,19
0.5 mm FIG. 13
0.1 mm FIGS. 1,2,7,8,10,17
1.
2.
7.
8
3
4.
9.
11.
12.
13.
5.
14.
15.
19.
6.
10.
17.
16.
20.
18.
21.

PLATE 20.—(1) *Temoropia mayumbaensis,* female, dorsal view; (2) lateral view; (3) posterior part of thora and abdomen, left side; (4) posterior part of thorax and abdomen, right side; (5) maxilliped; (6) fifth pair o feet; (7) male, dorsal view; (8) lateral view; (9) rostrum; (10) first antenna; (11) distal two segments of firs antenna; (12) fifth pair of feet; (13) *Metridia venusta,* female, dorsal view; (14) second foot (third exopoda segment omitted); (15) fifth pair of feet; (16) male, abdomen, dorsal view; (17) fifth pair of feet; (18) *Pleuro mamma xiphias,* female, dorsal view; (19) lateral view; (20) posterior part of thorax and abdomen, dorsal view (21) posterior part of thorax and abdomen, lateral view.

Remarks: The small size and large ventral otrusion on the genital segment (figs. 3, 4) ll identify the female. The geniculate right antenna and the pointed terminal segment of this antenna (figs. 10, 11) will aid in recognizing the male sex.

Family METRIDIIDAE

Metridia venusta Giesbrecht, 1889

(PLATE 20, FIGS. 13–17)

Pacific records: Vervoort, 1957.

ssel:	*Station*	*Occurrence*
Hugh M. Smith	144	1 juvenile female, 2.88 mm.; 1 male, 2.82 mm.

Remarks: This species is recognized by the ymmetrical furca. In both sexes the left rca is longer than the right one (figs. 13, 16).

Pleuromamma xiphias (Giesbrecht, 1888)

(PLATE 20, FIGS. 18–21, PLATE 21, FIGS. 1–5)

Pacific records: Vervoort, 1957. Also, Johnson, 42; Mori, 1942; Brodsky, 1950; Anraku, 1952; Honjo, 52; Anraku, 1954b; Tsuruta and Chiba, 1954a; 54b; Chiba, Tsuruta, and Maéda, 1955; Hida and ng, 1955; Nagaya et al., 1955; Chiba, 1956; Heinh, 1957b; Honjo et al., 1957; Heinrich, 1958b; mazi, 1958a.

Vessel:	*Station*	*Occurrence*			
		f. *typica*		f. *edentata*	f. *abyssalis*
		female	male	female	male
Orsom	10				

Vessel:	*Station*	*Occurrence*			
Hugh M. Smith	63	1 male, 4.28 mm.			

Remarks: The large spine-like protrusion on the forehead of this species (figs. 19, 3) readily distinguishes it from other species in the genus.

Pleuromamma abdominalis (Lubbock, 1856)

(PLATE 21, FIGS. 6–15)

Pacific records: Vervoort, 1957. Also, Johnson, 1942; Mori, 1942; Brodsky, 1950; Anraku, 1952; Honjo, 1952; Anraku, 1954a; 1954b; Tsuruta and Chiba, 1954b; Chiba, Tsuruta, and Maéda, 1955; Hida and King, 1955; Nagaya et al., 1955; Chiba, 1956; Heinrich, 1957b; Honjo et al., 1957; Heinrich, 1958a; Yamazi, 1958a.

ssel:	*Station*	*Occurrence* (*measurements in mm.; number of specimens in paren.*) f. *typica* female	f. *typica* male	f. *edentata* female	f. *abyssalis* male
Hugh M. Smith	94	3.02 (2)			
Do	29		3.13 (1)	2.75–3.06 (11)	3.06 (1)
Do	63			2.75–2.82 (2)	
Orsom	10		2.79–3.02 (3)		
Horizon	32	3.06 (1)			
Satsuma	32	2.85–3.13 (5)	2.99–3.06 (4)		

Remarks: All three forms of this species appeared in the above cited samples. Figures d descriptions of these have been presented Steuer (1932). The female of forma *abyslis* is not known. The female of forma *typica* d forma *edentata* are distinguished by the eth on the first and second antennal segents. In forma *typica* these segments each s a large tooth (fig. 6) while in forma *edenta* these segments have only small teeth (fig.)). Although Steuer mentions that segment 6 of the first antenna is smaller than segment 7 in forma *edentata*, these length differences e difficult to observe.

The male of forma *edentata* is unknown. Forma *typica* is easily recognized by the greatly asymmetrical and hairy abdomen (fig. 7) while the male of forma *abyssalis* has a less asymmetrical and less hairy abdomen (fig. 12). The small tooth on segment 17 (fig. 13) makes this specimen referable to what Steuer termed subform *thermophila* of forma *abyssalis*.

Pleuromamma indica Wolfenden, 1905

(PLATE 22, FIGS. 1–7)

Pacific records: Tanaka, 1953.

Vessel:	*Station*	*Occurrence*
Satsuma	32	1 male, 2.04 mm.

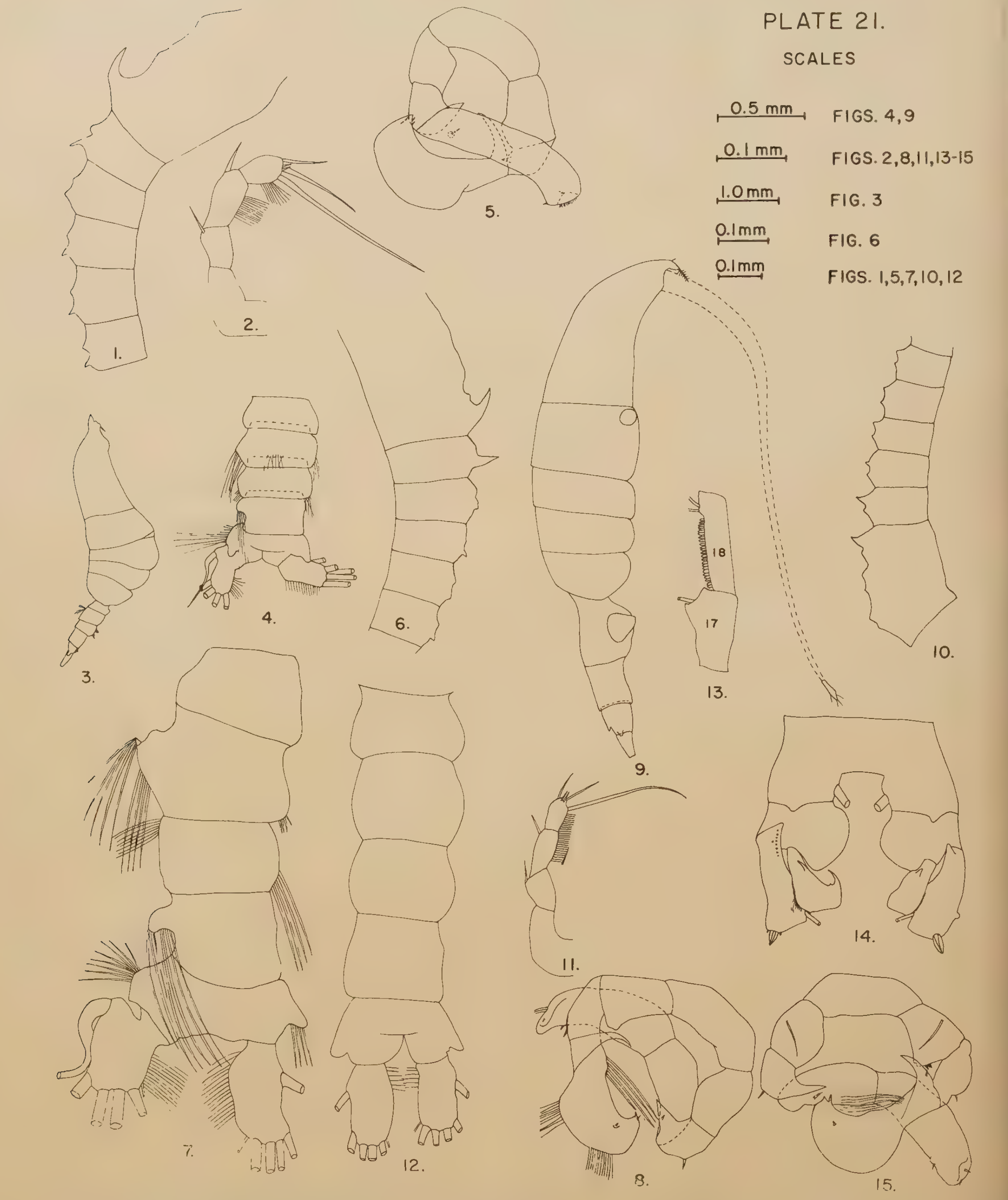


PLATE 21.
SCALES
0.5 mm FIGS. 4,9
0.1 mm FIGS. 2,8,11,13-15
1.0 mm FIG. 3
0.1 mm FIG. 6
0.1 mm FIGS. 1,5,7,10,12
1.
2.
5.
3.
4.
6.
9.
18
17
13.
10.
7.
12.
11.
14.
8.
15.

PLATE 21.—(1) *Pleuromamma xiphias*, female, proximal part of first antenna; (2) fifth foot; (3) male, later view; (4) abdomen, dorsal view; (5) fifth pair of feet; (6) *P. abdominalis* f. *typica*, female, proximal part first antenna; (7) male, abdomen, dorsal view; (8) fifth pair of feet; (9) *P. abdominalis* f. *edentata*, femal lateral view; (10) proximal part of first antenna; (11) fifth foot; (12) *P. abdominalis* f. *abyssalis*, male, abdome dorsal view; (13) segments 17 and 18 of right first antenna; (14) second pair of feet (distal end of exopods an endopods not shown); (15) fifth pair of feet.

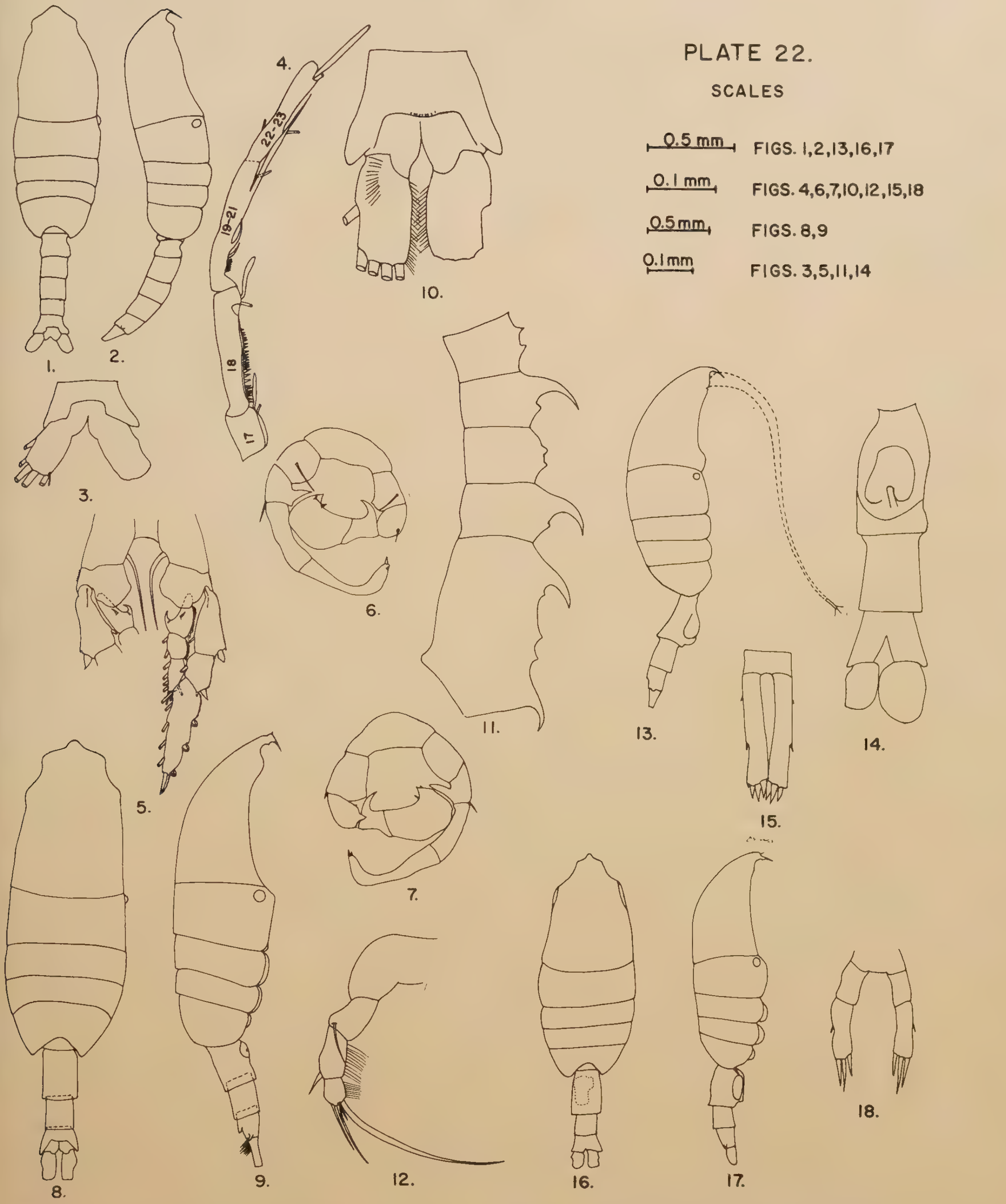


PLATE 22.
SCALES
0.5 mm FIGS. 1,2,13,16,17
0.1 mm FIGS. 4,6,7,10,12,15,18
0.5 mm FIGS. 8,9
0.1 mm FIGS. 3,5,11,14
1.
2.
3.
4.
22-23
19-21
18
17
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.

PLATE 22.—(1) *Pleuromamma indica*, male, dorsal view; (2) lateral view; (3) anal segment and furcae, sal view; (4) segments 17 to 23 of right first antenna; (5) second pair of feet (only part of one foot shown); fifth pair of feet, anterior side; (7) posterior side; (8) *P. quadrungulata* f. *typica*, female, dorsal view; lateral view; (10) anal segment and furcae, dorsal view; (11) proximal part of first antenna; (12) fifth foot;) *P. gracilis* f. *minima*, female, lateral view; (14) abdomen, ventral view; (15) fifth pair of feet; (16) *P. ealis*, female, dorsal view; (17) lateral view; (18) fifth pair of feet.

Remarks: Only a single male of this species was found. It is distinguished from males of *abdominalis* and other species by the symmetrical abdomen (fig. 1), divergent furcae (fig. 3) and absence of teeth on segment 17 of the right first antenna (fig. 4). The first segment of both endopods of *indica* are indented and claw-like (fig. 5) in contradistinction to *abdominalis* which has this claw-like indentation on only one endopod.

Pleuromamma quadrungulata (Dahl, 1893)

(PLATE 22, FIGS. 8–12)

Pacific records: Vervoort, 1957. Also, Brodsky, 1950.

Vessel:	Station	Occurrence
Hugh M. Smith	29	1 female, 3.77 mm.
Do	63	1 female, 3.51 mm.

Remarks: The above specimens are referable to forma *typica* Steuer, 1932. It is distinguished from forma *psychrophila* Steuer, 1931, by the presence of a large curved tooth on the fourth segment of the first antennae (fig. 11). In forma *psychrophila* this tooth is reduced in size and not curved.

Pleuromamma gracilis (Claus, 1863)

(PLATE 22, FIGS. 13–15)

Pacific records: Esterly, 1905; Scott, 1909; Farran, 1929; 1936; Mori, 1937; Tanaka, 1937; Dakin and Colefax, 1940; Johnson, 1942; Mori, 1942; Wilson, 1942; Brodsky, 1950; Wilson, 1950; Anraku, 1952; Honjo, 1952; Tanaka, 1953; Anraku, 1954b; Tsurut and Chiba, 1954b; Chiba, Tsuruta, and Maéda, 1955 Nagaya et al., 1955; Chiba, 1956; Heinrich, 1957b Honjo et al., 1957; Heinrich, 1958a; 1958b; Yamaz 1958a.

Vessel:	Station	Occurrence
Hugh M. Smith	94	1 female, 1.80 mm.
Do	29	6 females, 2.01–2.07 mm.
Do	63	1 female, 1.90 mm.
Horizon	32	1 female, 1.94 mm.
Satsuma	32	1 female, 1.97 mm.

Remarks: All the specimens obtained of thi species are referable to Steuer's (1932) forma *minima*. This form is distinguished from form *piseki* (Farran, 1929) and *maxima* (Steuer 1932) by the divergent margins of the ana segment (fig. 14) and by the fused second basa and exopodal segments of the fifth feet (fig 15). In most of the present specimens the lef furca is enlarged (fig. 14).

Pleuromamma borealis (Dahl, 1893)

(PLATE 22, FIGS. 16–18)

Pacific records: Farran, 1929; Brodsky, 1950; Wil son, 1950.

Vessel:	Station	Occurrence
Hugh M. Smith	63	1 female, 2.01 mm.
Orsom	10	1 female, 1.83 mm.
Satsuma	32	2 females, 1.90 mm.

Remarks: The long spines on the fifth fee of the female (fig. 18) distinguished this species from the preceding one.

Family CENTROPAGIDAE

Centropages gracilis (Dana, 1849)

(PLATE 23, FIGS. 1–3)

Pacific records: Scott, 1909; Yamada, 1933; Farran, 1936; Mori, 1937; Dakin and Colefax, 1940; Mori, 1942; Wilson, 1950; Tanaka, 1953; Tsuruta and Chiba, 1954b; Chiba, Tsuruta, and Maéda, 1955; Nagaya et al., 1955; Chiba, 1956; Honjo et al., 1957; Yamazi, 1958a.

Vessel:	Station	Occurrence
Hugh M. Smith	132	3 females, 1.90–1.97 mm.
Do	153	present.
Do	178	2 females, 2.00 mm.
Do	30	3 females, 1.97–2.01 mm.; 1 male, 2.04 mm.
Stranger	34	1 female, 1.90 mm.
Satsuma	32	1 male, 1.84 mm.

Remarks: The female is recognized by the spines on the sides on the second abdominal segment and the short spine-like protrusions on the inner sides of the second exopodal segments (fig. 1) of the fifth feet. The thumb of the chela of the right foot of the male has a

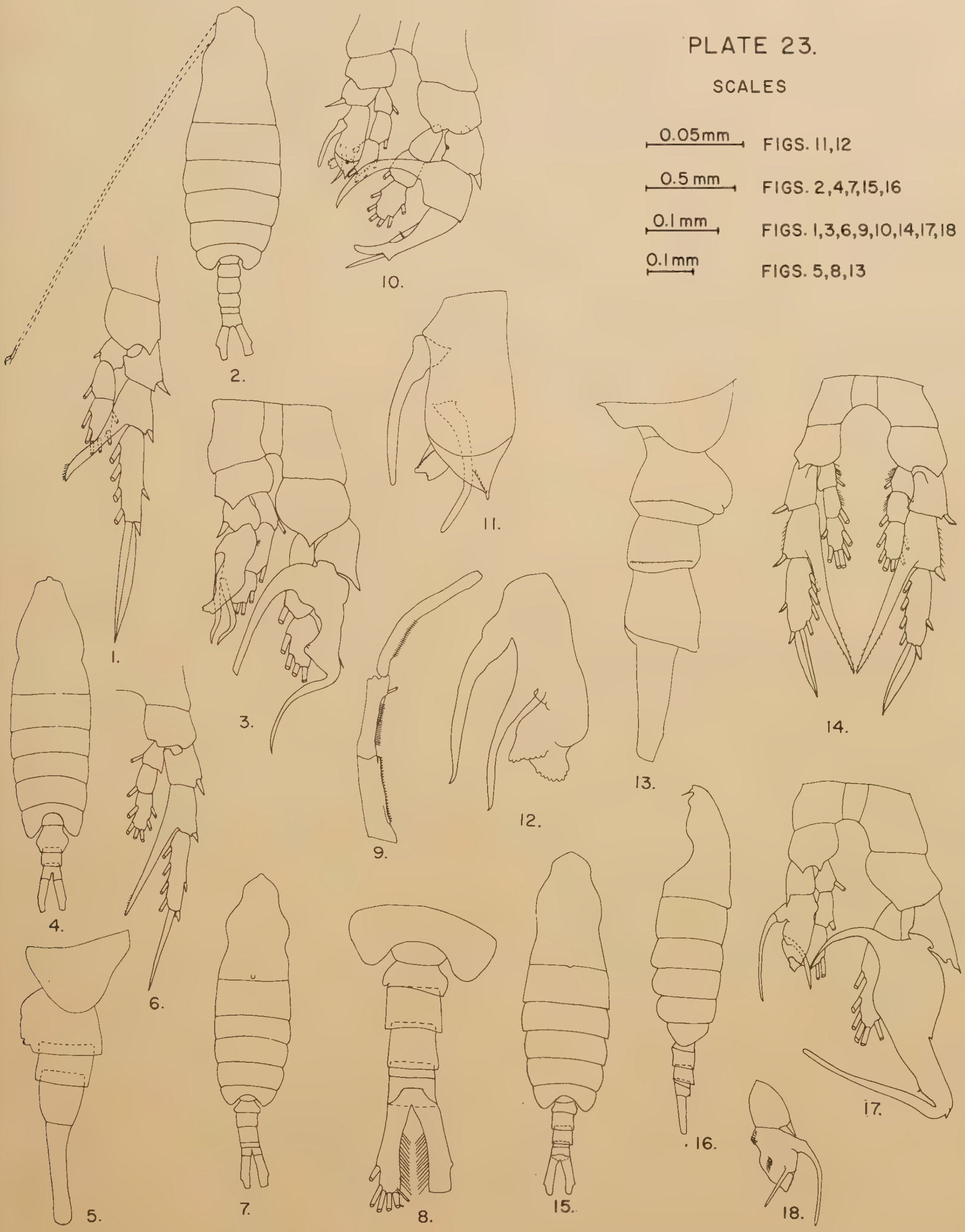


PLATE 23.
SCALES
0.05mm FIGS. 11,12
0.5 mm FIGS. 2,4,7,15,16
0.1 mm FIGS. 1,3,6,9,10,14,17,18
0.1mm FIGS. 5,8,13
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.

Plate 23.—(1) *Centropages gracilis*, female, fifth foot; (2) male, dorsal view; (3) fifth pair of feet; (4) *C. longatus*, female, dorsal view; (5) posterior part of thorax and abdomen, lateral view; (6) fifth foot; (7) male, orsal view; (8) posterior part of thorax and abdomen, dorsal view; (9) segments 17 to 21 of right first antenna; 10) fifth pair of feet; (11) terminal part of exopod of left fifth foot; (12) terminal part of exopod of left fifth oot, other side; (13) *C. calaninus*, female, posterior part of thorax and abdomen, lateral view; (14) fifth pair of eet; (15) male, dorsal view; (16) lateral view; (17) fifth pair of feet; (18) exopod of left fifth foot.

pronounced triangular protrusion which is absent in other species in the genus (fig. 3).

Centropages elongatus Giesbrecht, 1896

(PLATE 23, FIGS. 4–12)

Synonymy:

Centropages pacificus Chiba, 1956, Jour. Shimonoseki College of Fisheries, 6(1): 47–48.

Pacific records: Scott, 1909; Mori, 1937; 1942; Wilson, 1942; Johnson, 1954; Tsuruta and Chiba, 1954b; Chiba, Tsuruta, and Maéda, 1955; Nagaya et al., 1955; Yamazi, 1958a.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	153	1 female, 1.87 mm.
Horizon	32	2 males, 1.74, 1.76 mm.
Satsuma	32	1 female, 1.66 mm.

Remarks: The female genital segment is only slightly asymmetrical (figs. 4, 5) and the abdomen lacks the spines which are present in the preceding species and in a related species (*C. violaceus*). The spine-like extensions of the second exopodal segments of the fifth feet exceed the distal end of the third exopodal segments (fig. 6). The male is recognized by the structure of the fifth feet, particularly the long external spine near the distal end of the thumb (fig. 10) and the form of the left exopod (figs. 11, 12).

Chiba (1956) has described a new species, *C. pacificus* (based on males), from specimens collected in the Bikini area. I believe these specimens are the males of *C. elongatus*, a species which has also been reported from Bikini by Johnson (1954).

Mori (1937) stated in his discussion of this species that the last thoracic segments of the female are pointed. He also presented a figure showing this point on one lateral margin. However, no mention was made of the pointed margins of the last thoracic segments by Giesbrecht (1896) in his original description of the species nor in the synopsis of this species presented later by Giesbrecht and Schmeil (1898). The latter authors stated that *C. elongatus* is related to *C. violaceus* which has round posterior thoracic margins. The present specimens also have rounded margins (fig. 5).

Centropages calaninus (Dana, 1849)

(PLATE 23, FIGS. 13–18)

Pacific records: Scott, 1909; Farran, 1936; Mori, 1937; Dakin and Colefax, 1940; Mori, 1942; Wilson, 1942; 1950; Tanaka, 1953; Tsuruta and Chiba, 1954b; Chiba, Tsuruta, and Maéda, 1955; Nagaya et al., 1955; Chiba, 1956; Gilmartin, 1958; Yamazi, 1958a.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	30	1 female, 2.18 mm.; 1 male, 2.06 mm.
Horizon	32	3 females, 1.97–2.04 mm.; 5 males, 1.80–2.00 mm.

Remarks: The anal segment of the female has a small knob on the ventral surface near the posterior end and the spine-like protrusions of the second exopodal segments of the fifth feet exceed the tip of the third exopodal segments (figs. 13, 14). The male is recognized by the structure of the fifth feet, especially the long and bent thumb of the chela (fig. 17).

Family LUCICUTIIDAE

Lucicutia flavicornis (Claus, 1863)

(PLATE 24, FIGS. 1–4)

Pacific records: Esterly, 1905; Scott, 1909; Farran, 1929; Mori, 1937; Dakin and Colefax, 1940; Johnson, 1942; Mori, 1942; Wilson, 1942; Davis, 1949; Brodsky, 1950; Wilson, 1950; Anraku, 1952; Honjo, 1952; Tanaka, 1953; Anraku, 1954b; Tsuruta and Chiba, 1954b; Chiba, Tsuruta, and Maéda, 1955; Motoda and Anraku, 1955; Nagaya et al., 1955; Chiba, 1956; Heinrich, 1957b; Honjo et al., 1957; Heinrich, 1958a; Yamazi, 1958a.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	94	12 females, 1.46–1.90 mm.; 7 males, 1.43–1.77 mm.
Do	132	3 males, 1.29–1.66 mm.
Do	144	4 females, 1.63–1.80 mm.; 5 males, 1.44–1.48 mm.
Do	178	3 females, 1.36–1.53 mm.; 7 males, 1.28–1.42 mm.

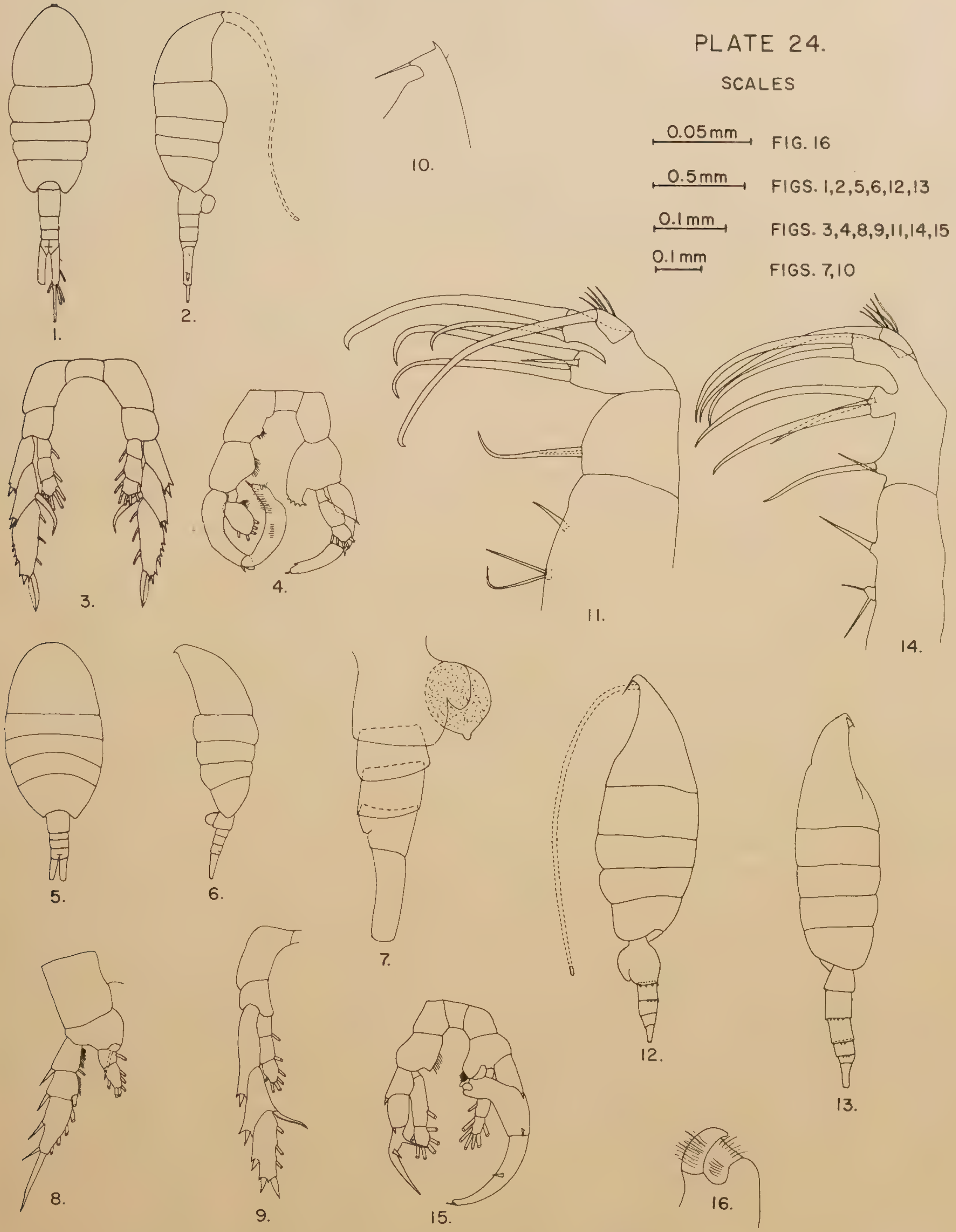


PLATE 24.
SCALES
0.05 mm FIG. 16
0.5 mm FIGS. 1,2,5,6,12,13
0.1 mm FIGS. 3,4,8,9,11,14,15
0.1 mm FIGS. 7,10
1.
2.
10.
3.
4.
11.
14.
5.
6.
7.
12.
13.
8.
9.
15.
16.

Plate 24.—(1) *Lucicutia flavicornis,* female, dorsal view; (2) lateral view; (3) fifth pair of feet; (4) male, fifth pair of feet; (5) *L. ovalis,* female, dorsal view; (6) lateral view; (7) abdomen, lateral view; (8) first foot; (9) fifth foot; (10) *Heterorhabdus spinifrons,* female, forehead, lateral view; (11) second maxilla; (12) *H. papilliger,* female, lateral view; (13) male, lateral view; (14) second maxilla; (15) fifth pair of feet; (16) distal end of protrusion of second right exopodal segment.

Vessel:	Station	Occurrence
Do	31	3 females, 1.41–1.55 mm.
Do	29	present.
Stranger	34	1 female, 1.39 mm.
Satsuma	32	1 female, 1.26 mm.

Remarks: The female is distinguished from other species of the genus by the short anal segment (figs. 1, 2) and by the form of the fifth feet (fig. 3). The male is recognized by the protrusion of the second basipodal segment of the left foot and the long terminal segment of the right exopod (fig. 4).

Other authors, including Farran, 1929, mention that considerable variation occurs in the length of this species. In at least one collection (*Smith* 94), two size groups were noted as follows: females 1.46–1.53 (6); 1.87–1.90 (6); males 1.39–1.53 (7); 1.77 (1) mm.

Lucicutia ovalis Wolfenden, 1911

(Plate 24, figs. 5–9)

Pacific records: Farran, 1929; 1936; Mori, 1937; Wilson, 1950; Tanaka, 1953; Anraku, 1954b; Tsuruta and Chiba, 1954b; Chiba, Tsuruta, and Maéda, 1955; Motoda and Anraku, 1955; Nagaya et al., 1955; Chiba, 1956; Honjo et al., 1957; Yamazi, 1958a.

Vessel:	Station	Occurrence
Hugh M. Smith	132	2 females, 1.32, 1.36 mm.
Do	153	1 female, 1.37 mm.
Do	178	3 females, 1.34–1.36 mm.
Do	63	1 female, 1.46 mm.
Stranger	34	1 female, 1.39 mm.
Orsom	10	present.
Satsuma	32	1 female, 1.44 mm.

Remarks: The female is most easily recognized by its small size, the two-segmented endopod of the first feet (fig. 8), and the structure of the fifth feet (fig. 9).

Family HETERORHABDIDAE

Heterorhabdus spinifrons (Claus, 1863)

(Plate 24, figs. 10–11)

Pacific records: Vervoort, 1957. Also, Brodsky, 1950; Tanaka, 1953.

Vessel:	Station	Occurrence
Hugh M. Smith	144	present.
Do	29	3 females, 2.69–3.57 mm.; 3 males, 3.04–3.20 mm.
Do	63	1 male, 2.41 mm.
Satsuma	32	3 females, 2.10–2.18 mm.

Remarks: In both sexes the forehead is prolonged into a point (fig. 10), a character which will identify this species. In the female, one of the distal 3 spines of the maxilliped is small and slender (fig. 11).

Heterorhabdus papilliger (Claus, 1863)

(Plate 24, figs. 12–16)

Pacific records: Esterly, 1905; Scott, 1909; Farran, 1929; 1936; Mori, 1937; Tanaka, 1937; Dakin and Colefax, 1940; Johnson, 1942; Mori, 1942; Wilson, 1942; Brodsky, 1950 Wilson, 1950; Anraku, 1952; Honjo, 1952; Tanaka, 1953; Anraku, 1954a; 1954b; 1954c; Chiba, Tsuruta, and Maéda, 1955; Motoda and Anraku, 1955; Nagaya et al., 1955; Chiba, 1956; Heinrich, 1957b; Yamazi 1958a.

Vessel:	Station	Occurrence
Hugh M. Smith	94	2 females, 2.04, 2.07 mm.; 3 males, 1.80–1.94 mm.
Do	132	2 females, 1.87, 1.90 mm.; 1 male, 1.87 mm.
Do	144	1 female, 2.14 mm.; 1 male, 2.11 mm.
Do	178	6 females, 1.80–1.87 mm.; 6 males, 1.70–1.84 mm.
Do	29	1 female, 2.00 mm.
Do	31	4 females, 1.90–1.94 mm.; 1 male, 1.97 mm.
Do	63	2 females, 1.77, 1.97 mm.
Stranger	34	1 female, 1.94 mm.
Orsom	10	1 female, 1.84 mm.

Remarks: The female forehead is rounded (fig. 12) and the 3 distal spines of the maxilliped are all about equal in length in both sexes (fig. 14).

Family AUGAPTILIDAE

Haloptilus acutifrons (Giesbrecht, 1892)

(Plate 25, figs. 1–8)

Pacific records: Vervoort, 1957. Also, Johnson, 1942; odsky, 1950; Tanaka, 1953; Anraku, 1954b; Chiba, uruta, and Maéda, 1955; Nagaya et al., 1955; Chiba, 6; Yamazi, 1958a.

ssel:	Station	Occurrence
Hugh M. Smith	94	1 female, 3.80 mm.

Remarks: Although closely resembling *H. ycephalus*, *H. acutifrons* may be distinguished (1) its small size, (2) less produced fore- ad (fig. 1) and (3) structure of the gnathal e of the mandible (fig. 3).

Haloptilus fertilis (Giesbrecht, 1892)

(Plate 25, figs. 9–11)

acific records: none.

ssel:	Station	Occurrence
Hugh M. Smith	32	1 male, 2.47 mm.

Remarks: The male is recognized by its all size and structure of the fifth feet (fig.).

Haloptilus longicornis (Claus, 1863)

acific records: Scott, 1909; Farran, 1929; 1936; ri, 1937; Johnson, 1942; Mori, 1942; Wilson, 1942; dsky, 1950; Wilson, 1950; Tanaka, 1953; Yamazi, 3c; Chiba, Tsuruta, and Maéda, 1955; Nagaya et 1955; Chiba, 1956; Heinrich, 1957b; Honjo et al., 7; Heinrich, 1958b; Yamazi, 1958a.

sel:	Station	Occurrence
Hugh M. Smith	94	present.
Do	132	9 females, 1.80–1.90 mm.
Do	144	present.
Do	153	Do
Do	178	Do
Do	31	Do
Do	63	Do
Stranger	34	Do
Orsom	10	Do
Horizon	32	Do
Satsuma	32	5 females, 1.77–1.83 mm.

emarks: The long first antennae which ex- d the end of the furca and the knob-like ton on the forehead will identify the female. males were found.

As the occurrence records indicate, this was a widespread species in the present collections. It was also the most abundant species of *Haloptilus* and occurred in fair numbers in several samples (*Smith* 94, 144, 31).

Haloptilus ornatus (Giesbrecht, 1892)

(Plate 25, figs. 12–16)

Pacific records: Scott, 1909; Mori, 1937; Johnson, 1942; Wilson, 1942; Wilson, 1950; Tanaka, 1953; Anraku, 1954b; Chiba, Tsuruta, and Maéda, 1955; Nagaya et al., 1955; Chiba, 1956.

Vessel:	Station	Occurrence
Hugh M. Smith	63	1 female, 4.56 mm.

Remarks: This is a large species and has a rounded forehead. As in other species of *Haloptilus*, the form of the gnathal lobe of the mandible is also diagnostic (fig. 13).

Haloptilus spiniceps (Giesbrecht, 1892)

(Plate 25, figs. 17–20; plate 26, figs. 1–5)

Pacific records: Scott, 1909; Farran, 1929; 1936; Mori, 1937; Dakin and Colefax, 1940; Johnson, 1942; Wilson, 1942; 1950; Tanaka, 1953.

Vessel:	Station	Occurrence
Hugh M. Smith	94	1 female, 3.99 mm.
Stranger	34	1 female, 3.70 mm.
Orsom	10	present.
Horizon	32	1 female, 3.80 mm.
Satsuma	32	1 female, 3.80 mm.

Remarks: The short pointed forehead (fig. 17) which is curved downward in lateral view (fig. 18) and the structure of the gnathal lobe of the mandible (fig. 20) will identify the female of this species. No male has been found.

Haloptilus austini Grice, 1959

Pacific records: Grice, 1959.

Vessel:	Station	Occurrence
Hugh M. Smith	94	2 females, 3.16, 3.33 mm.

Remarks: I have recently described this species. It has a rounded forehead and, as in other species of *Haloptilus*, the gnathal lobe of the mandible is diagnostic.

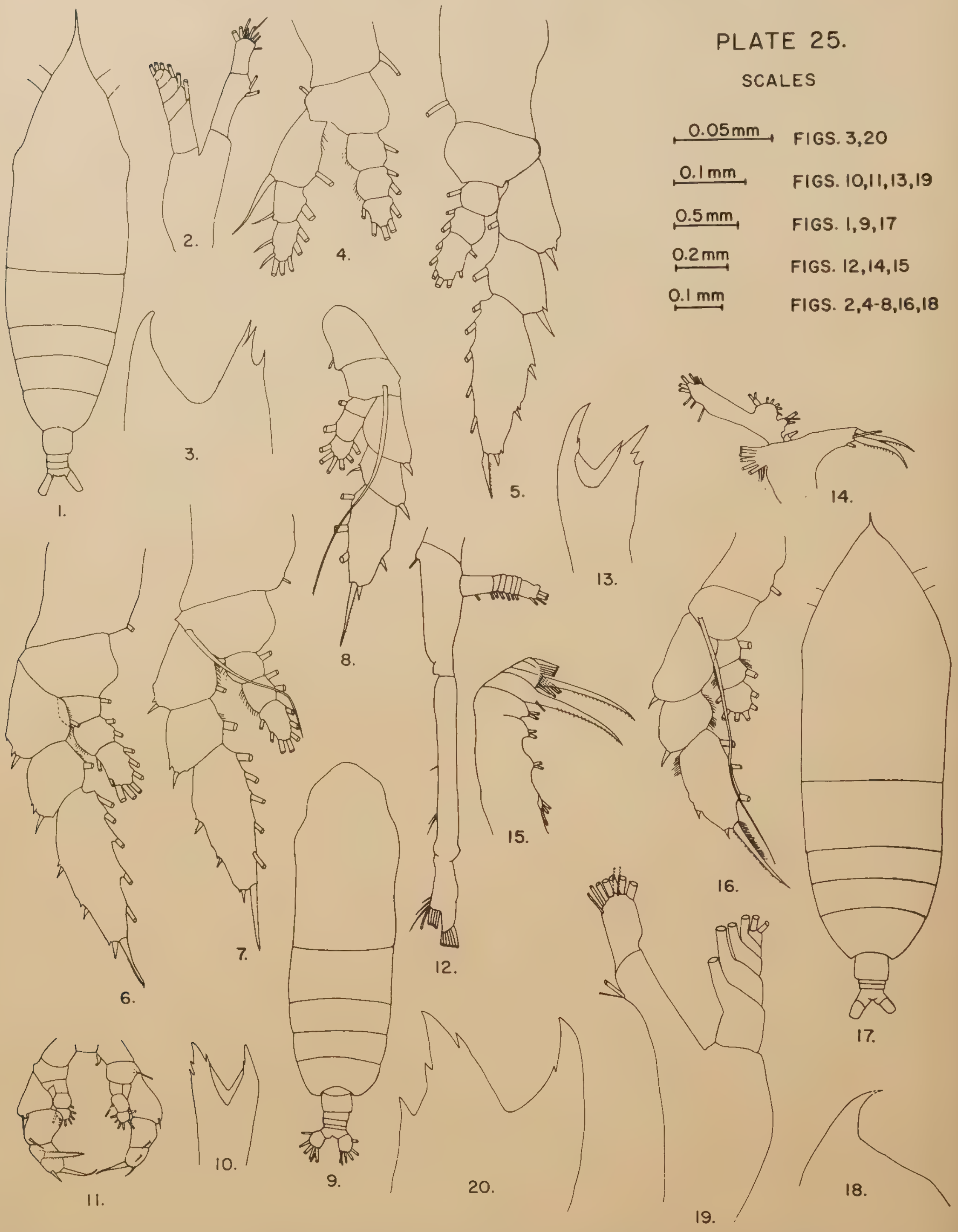


PLATE 25.
SCALES
0.05mm FIGS. 3,20
0.1mm FIGS. 10,11,13,19
0.5mm FIGS. 1,9,17
0.2mm FIGS. 12,14,15
0.1 mm FIGS. 2,4-8,16,18
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.
19.
20.

PLATE 25.—(1) *Haloptilus acutifrons*, female, dorsal view; (2) mandible palpus; (3) gnathal lobe of mandib (4) first foot; (5) second foot; (6) third foot; (7) fourth foot; (8) fifth foot; (9) *H. fertilis*, male, dorsal vie (10) gnathal lobe of mandible; (11) fifth pair of feet; (12) *H. ornatus*, female, second antenna; (13) gnath lobe of mandible; (14) first maxilla; (15) second maxilla; (16) fifth foot; (17) *H. spiniceps*, female, dorsal vie (18) forehead, lateral view; (19) mandible palpus; (20) gnathal lobe of mandible.

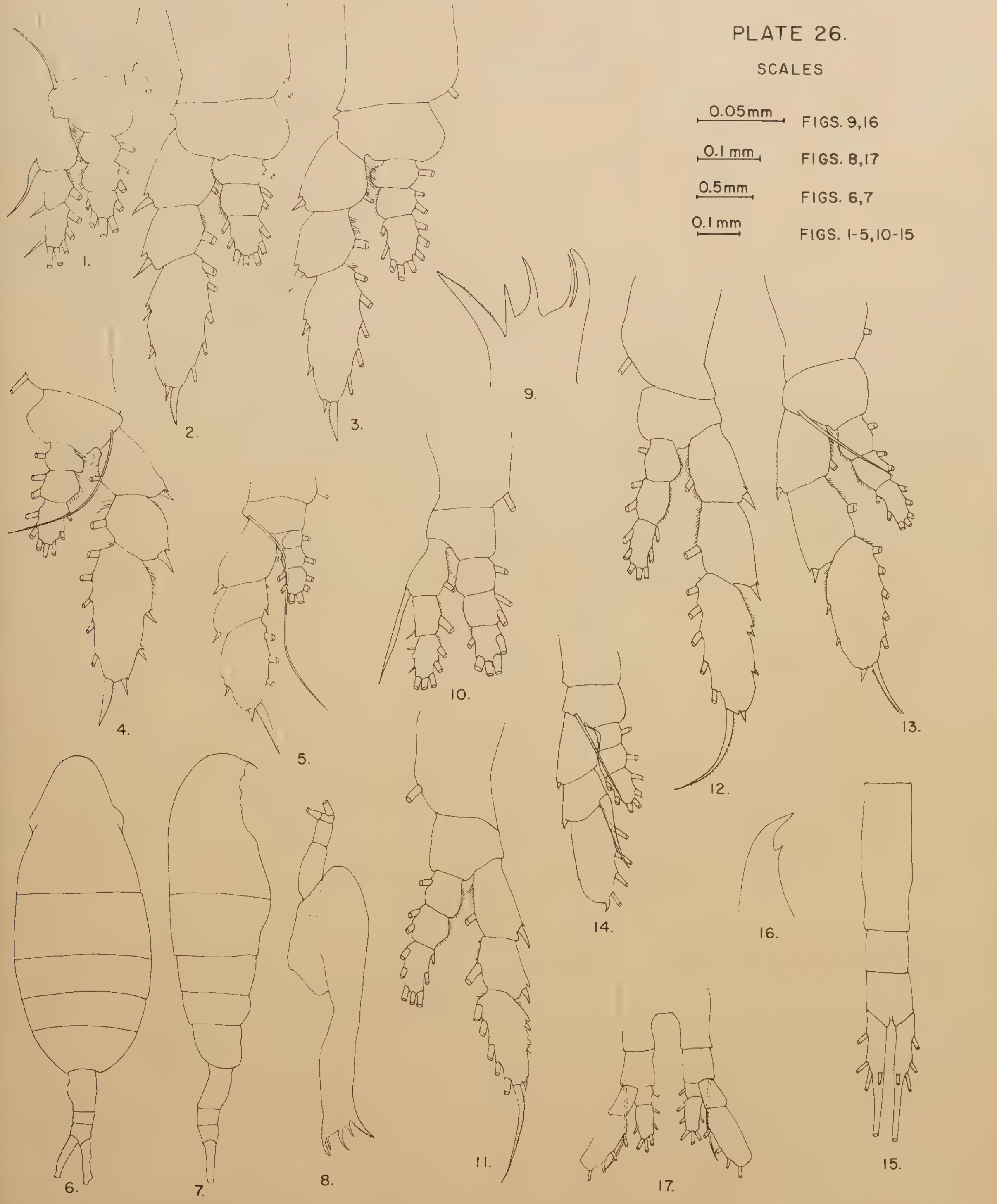


PLATE 26.
SCALES
0.05mm FIGS. 9,16
0.1 mm FIGS. 8,17
0.5mm FIGS. 6,7
0.1 mm FIGS. 1-5,10-15
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.

Plate 26.—(1) *Haloptilus spiniceps*, female, first foot; (2) second foot; (3) third foot; (4) fourth foot; fifth foot; (6) *Augaptilus longicaudatus*, female, dorsal view; (7) lateral view; (8) mandible; (9) gnathal lobe mandible; (10) first foot; (11) second foot; (12) third foot; (13) fourth foot; (14) fifth foot; (15) *Euaugap-* *s hecticus*, female, abdomen; (16) gnathal lobe of mandible; (17) fifth pair of feet.

Augaptilus longicaudatus (Claus, 1863)

(Plate 26, figs. 6–14)

Pacific records: Esterly, 1905; Scott, 1909; Farran, 1929; 1936; Wilson, 1942; Brodsky, 1950; Wilson, 1950; Tanaka, 1953.

Vessel:	Station	Occurrence
Hugh M. Smith	94	1 female, 3.60 mm.

Remarks: The asymmetrical genital segment (fig. 6), mandibular dentition (fig. 8), and structure of the fifth feet (fig. 14) will identify the female. No males were observed in the present collections.

Euaugaptilus hecticus (Giesbrecht, 1889)

(Plate 26, figs. 15–17)

Pacific records: Farran, 1929; Wilson, 1950; Tanak 1953. As *Augaptilus hecticus;* Scott, 1909.

Vessel:	Station	Occurrence
Hugh M. Smith	31	2 females, 2.70 mm.
Stranger	34	1 female, 2.28 mm.
Satsuma	32	1 female, 2.38 mm.

Remarks: The very long genital segmen (fig. 15), claw-like mandibular blade (fig. 16 and the 2-segmented exopods of the fifth fee (fig. 17) serve to identify this species.

Family ARIETELLIDAE

Arietellus setosus Giesbrecht, 1892

(Plate 27, figs. 1–4)

Pacific records: Esterly, 1905; Scott, 1909; Esterly, 1911; Farran, 1929; Johnson, 1942; Wilson, 1942; Brodsky, 1950; Wilson, 1950.

Vessel:	Station	Occurrence
Hugh M. Smith	63	1 male, 3.99 mm.

Remarks: The posterior thoracic margins are widely divergent (figs. 1, 3) and the forehead terminates in an acute point (fig. 2). Only the male has been found in the present samples.

Arietellus giesbrechti Sars, 1905

(Plate 27, fig. 5)

Pacific records: Wilson, 1950; Tanaka, 1953.

Vessel:	Station	Occurrence
Hugh M. Smith	29	1 male, 4.75 mm.

Remarks: In the male the left posterior thoracic margin is slightly longer than the right. The fifth feet, shown here (fig. 5), are also diagnostic. No females were observed.

Arietellus plumifer Sars, 1905

(Plate 27, figs. 6–10)

Pacific records: Wilson, 1950.

Vessel:	Station	Occurrence
Hugh M. Smith	94	1 juvenile female.
Do	63	1 female, 5.51 mm.

Remarks: The posterior margins of th thorax are symmetrical and turned upwar (figs. 6, 7, 9), and the head has a small poin (figs. 7, 8). No males were found.

Arietellus aculeatus (T. Scott, 1894)

(Plate 27, figs. 11–14)

Pacific records: Scott, 1909; Farran, 1929; Wilso 1950.

Vessel:	Station	Occurrence
Hugh M. Smith	63	1 juvenile female, 4.08 mm.

Remarks: The forehead is produced into long point (fig. 11). The posterior thorac margins are asymmetrical and the spinous pr trusion of the right side is more divergent an longer than the one on the left (figs. 11, 13).

Farran (1929) has suggested that *A. arma tus* Wolfenden, 1911 is probably a synonym o *A. aculeatus*. Wilson (1950), however, recog nized *armatus* as a valid species and redescribe both sexes.

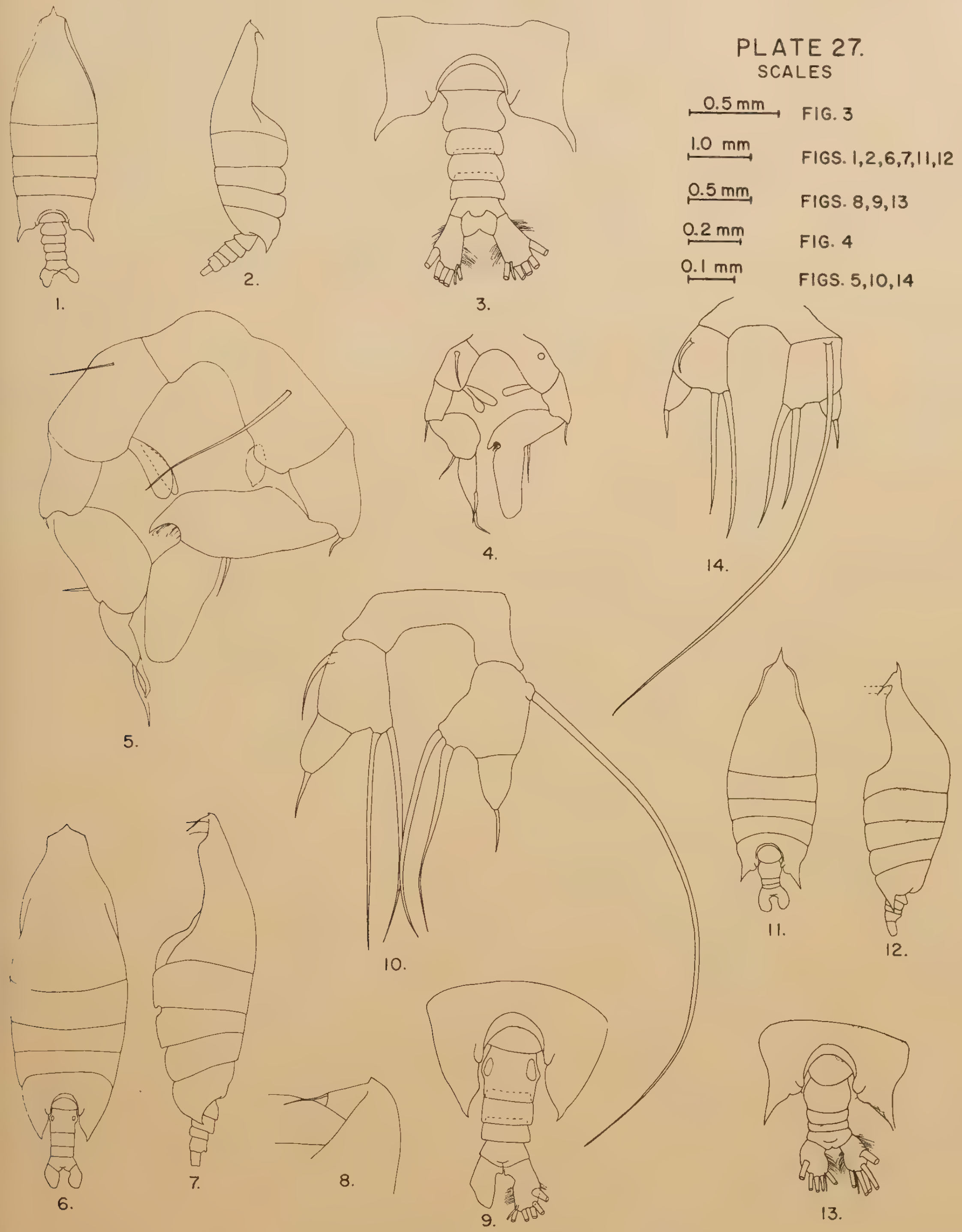


PLATE 27.
SCALES
0.5 mm FIG. 3
1.0 mm FIGS. 1,2,6,7,11,12
0.5 mm FIGS. 8,9,13
0.2 mm FIG. 4
0.1 mm FIGS. 5,10,14
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.

PLATE 27.—(1) *Arietellus setosus*, male, dorsal view; (2) lateral view; (3) posterior part of thorax and omen, dorsal view; (4) fifth pair of feet; (5) *A. giesbrechti*, male, fifth pair of feet; (6) *A. plumifer*, female, sal view; (7) lateral view; (8) forehead, lateral view; (9) posterior part of thorax and abdomen, dorsal view;) fifth pair of feet; (11) *A. aculeatus*, juvenile female, dorsal view; (12) lateral view; (13) posterior t of thorax and abdomen, dorsal view; (14) fifth pair of feet.

Family CANDACIIDAE

Candacia longimana (Claus, 1863)

(Plate 28, figs. 1–12)

Pacific records: Scott, 1909; Farran, 1929; 1936; Mori, 1937; 1942; Wilson, 1942; 1950; Honjo, 1952; Tanaka, 1953; Anraku, 1954b; Tsuruta and Chiba, 1954b; Chiba, Tsuruta, and Maéda, 1955; Nagaya et al., 1955; Chiba, 1956; Heinrich, 1957b; Honjo et al., 1957; Yamazi, 1958a.

Vessel:	*Station*	*Occurrence*
Horizon	32	2 females, 2.82, 2.92 mm.; 1 male, 2.69 mm.
Satsuma	32	1 female, 2.89 mm.

Remarks: Twelve species of *Candacia* were found in the collections. For each species, excepting *C. guggenheimi* which has recently been described (Grice and Jones, 1960), I have usually included figures of the dorsal and lateral views of both sexes. Figures are also given of the fifth feet of each species and, for most species, figures of certain of the cephalic appendages (gnathal lobe of the mandible, second maxilla and maxilliped) are given. The females of the species herein described are easily recognized by the forms of the genital segment and fifth feet. The males are recognized by the character of the spine-like protrusion of the right posterior thoracic margin, the structure of the abdomen and the form of the fifth feet.

The female of *C. longimana* has a symmetrical genital segment (fig. 1), the basal tooth of the mandible is tricuspate (fig. 3), and the fifth foot terminates in 3 sub-equal points (figs. 4, 5). The right posterior thoracic margin of the male ends in an irregular protrusion (figs. 6, 7) which in lateral view is seen to turn upward (fig. 9). The right side of the genital segment has a large finger-like protrusion. The right fifth foot is chelate (fig. 11) and the distal margin of the last segment of the left foot ends in 3 small points (fig. 12).

Candacia guggenheimi Grice and Jones, 1960

Pacific records: Grice and Jones, 1960.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	29	present.

Remarks: This species has recently been described elsewhere (Grice and Jones, 1960). The genital segment of the female has two sma spines on the dorsal surface and the genital seg ment of the male has a bilobed protrusion ex tending from the right side.

Candacia tenuimana (Giesbrecht, 1889)

(Plate 28, figs. 13–18; plate 29, figs. 1–4)

Pacific records: Scott, 1909; Johnson, 1942; Wi son, 1942; 1950.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	29	1 female, 2.07 mm.; 1 male, 2.20 mm.

Remarks: The female genital segment i slightly asymmetrical, the right side being mor produced than the left (fig. 13, 15). The basa tooth of the mandible has 2 unequal cusps (fig 17). The innermost spine-like protrusion o the distal segment of the fifth foot (fig. 18) i considerably longer than the other two. Th spine-like protrusion on the right posterio thoracic margin of the male has a bifid tip (fig 1, 2) and the genital segment is produced t the right in the form of a narrow, curved spine-like process (fig. 2). As in the preced ing species, the right fifth foot is chelate (fig 4).

Candacia aethiopica (Dana, 1849)

(Plate 29, figs. 5–16)

Pacific records: Streets, 1877; Esterly, 1905; Scot 1909; Farran, 1929; Yamada, 1933a; Tanaka, 1935b Farran, 1936; Mori, 1937; Dakin and Colefax, 1940 Johnson, 1942; Mori, 1942; Wilson, 1942; 1950; Tanaka 1953; Anraku, 1954b; Tsuruta and Chiba, 1954b; Chiba Tsuruta, and Maéda, 1955; Nagaya et al., 1955; Chiba 1956; Honjo et al., 1957; Gilmartin, 1958.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	30	1 male, 2.24 mm.
Horizon	32	1 female, 2.21 mm.; 3 males 2.18–2.2 mm.
Satsuma	32	1 female, 1.97 mm.

Remarks: Of the two spine-like protrusion on the female genital segment, the one on th left is the larger (figs. 5, 7). The basal tootl of the mandible has 3 cusps, the middle one o which is the larger (fig. 9). The distal seg ment of the fifth foot has 1 external spine,

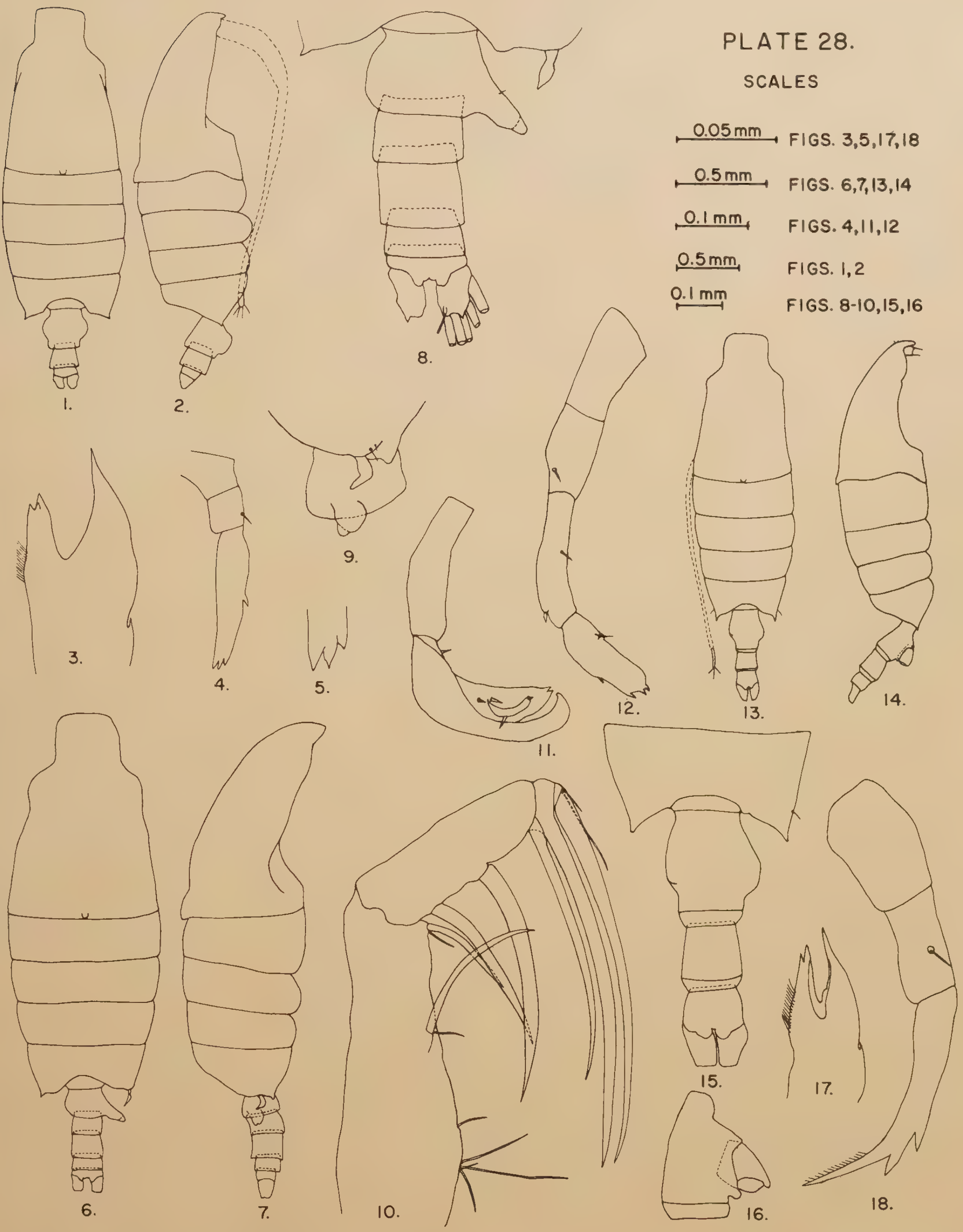


PLATE 28.
SCALES
0.05 mm FIGS. 3,5,17,18
0.5 mm FIGS. 6,7,13,14
0.1 mm FIGS. 4,11,12
0.5 mm FIGS. 1,2
0.1 mm FIGS. 8-10,15,16
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.

Plate 28.—(1) *Candacia longimana,* female, dorsal view; (2) lateral view; (3) gnathal lobe of mandible; (4) fifth foot; (5) tip of fifth foot; (6) male, dorsal view; (7) lateral view; (8) abdomen, dorsal view; (9) posterior lateral corner of thorax and genital segment, right side; (10) second maxilla; (11) right fifth foot; (12) left fifth foot; (13) *C. tenuimana,* female, dorsal view; (14) lateral view; (15) posterior part of thorax and abdomen, dorsal view; (16) genital segment, lateral view; (17) gnathal lobe of mandible; (18) fifth foot.

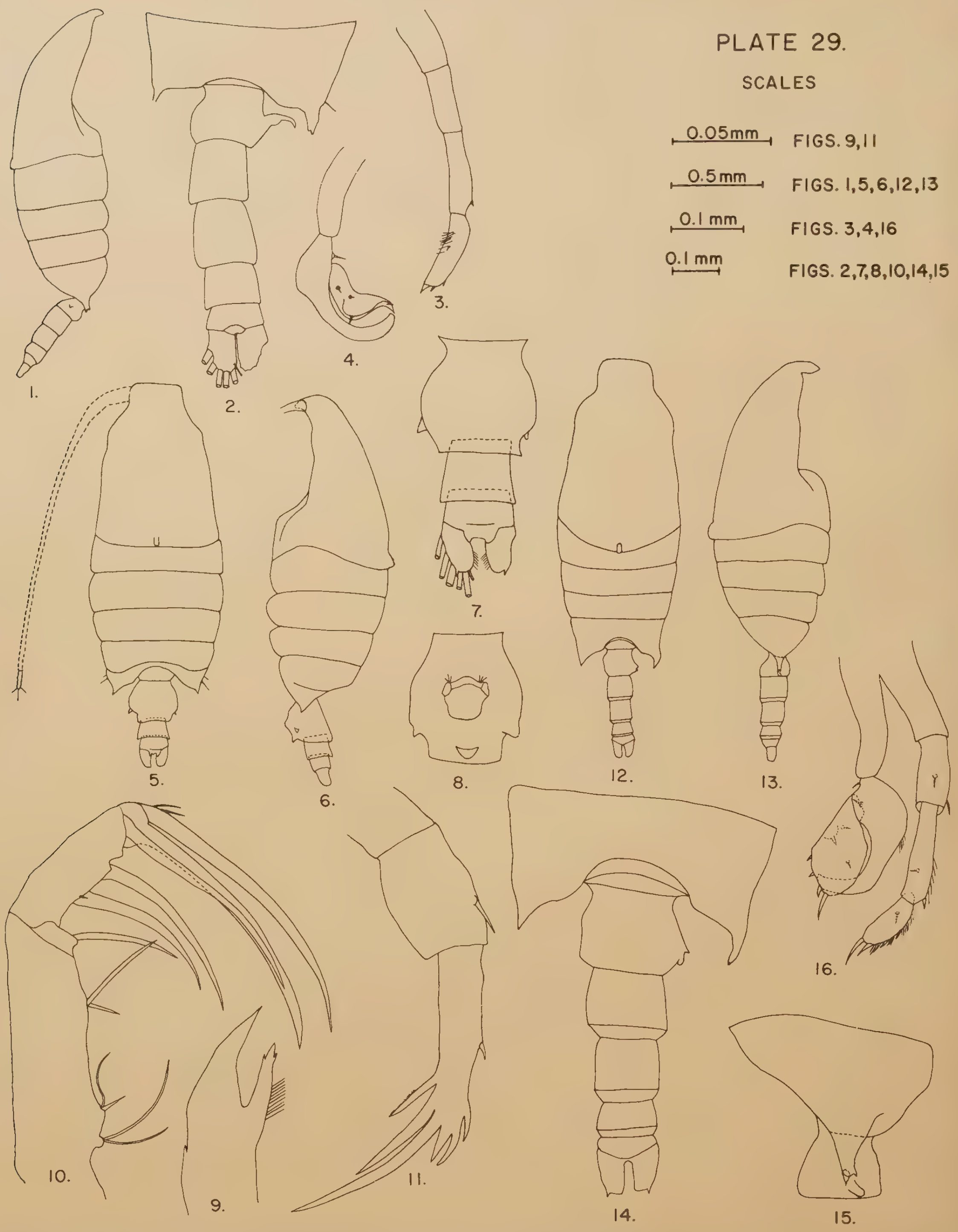


PLATE 29.
SCALES
0.05mm FIGS. 9,11
0.5mm FIGS. 1,5,6,12,13
0.1 mm FIGS. 3,4,16
0.1 mm FIGS. 2,7,8,10,14,15
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.

PLATE 29.—(1) *Candacia tenuimana*, male, lateral view; (2) posterior part of thorax and abdomen, dorsa view; (3) left fifth foot; (4) right fifth foot; (5) *C. aethiopica*, female, dorsal view; (6) lateral view; (7) abdome dorsal view; (8) genital segment, ventral view; (9) gnathal lobe of mandible; (10) second maxilla; (11) fifth foot (12) male, dorsal view; (13) lateral view; (14) posterior part of thorax and abdomen, dorsal view; (15) posterio lateral corner of thorax and genital segment, right side; (16) fifth pair of feet.

minal points and 3 internal, apparently un- iculated, setae (fig. 11). The male has a d spine-like protrusion (lateral view) ex- ding from the right posterior margin of the orax (figs. 13, 15). There is a rounded tu- cle and a spine-like point arising from the ht side of the genital segment (fig. 14). The la of the right fifth foot is broad and spin- (fig. 16).

Candacia pachydactyla (Dana, 1849)

(PLATE 30, FIGS. 1–9)

acific records: Scott, 1909; Tanaka, 1935; Mori, 7; Dakin and Colefax, 1940; Wilson, 1942; 1950; ba, 1952c; Tanaka, 1953; Tsuruta and Chiba, 1954b; ba, Tsuruta, and Maéda, 1955; Hida and King, 5; Nagaya et al., 1955; Chiba, 1956; Honjo et al., 7; Yamazi, 1958a.

ssel:	*Station*	*Occurrence*
Hugh M. Smith	132	2 males, 2.52 mm.
Do	153	1 female, 2.82 mm.; 1 male, 2.07 mm.
Do	178	2 males, 2.52 mm.
Do	30	4 females, 2.48–2.55 mm.; 1 male, 2.48 mm.
Do	63	1 female, 2.88 mm.; 4 males, 2.45–2.72 mm.
Stranger	34	3 females, 2.62–2.65 mm.; 2 males, 2.38, 2.52 mm.
Orsom	10	1 male, 2.48 mm.
Horizon	32	6 females, 2.55–2.62 mm.; 6 males, 2.31–2.55 mm.

Remarks: This is a robust species and is sily distinguished by the coarse spine-like otrusions of the genital segment of the fe- ale (figs. 1, 2). The basal tooth of the man- ble ends in 3 very unequal cusps (fig. 3). The stal segment of the fifth feet ends in 3 points, e innermost one of which is curved (fig. 4). e right posterior margin of the thorax of the ale (figs. 5, 6) is similar to that of *C. aethio- ca* but the protrusion of the genital segment quite large (fig. 7). The thumb of the chela the right fifth foot ends in a long spine as es the distal segment of the left foot (figs. 9).

Candacia curta (Dana, 1849)

(PLATE 30, FIGS. 10–14; PLATE 31, FIGS. 1–3)

Pacific records: Esterly, 1905; Scott, 1909; Farran, 1935b; Farran, 1936; Mori, 1937; Johnson, 1942; Wilson, 1942; 1950; Tanaka, 1953; Tsuruta and Chiba, 1954b; Chiba, Tsuruta, and Maéda, 1955; Nagaya et al., 1955; Chiba, 1956; Honjo et al. 1957; Yamazi, 1958a. As *C. bicornuta;* Mori, 1932.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	29	2 females, 2.48. 2.62 mm.; 2 males, 2.28, 2.34 mm.
Orsom	10	1 female, 2.44 mm.; 1 male, 2.20 mm.
Horizon	32	1 female, 2.58 mm.

Remarks: The female genital segment is slightly asymmetrical in dorsal view (fig. 10) and has a spine-like protrusion on the ventral side (fig. 11). This spine-like protrusion originates from the right side of the segment (fig. 12). The basal tooth of the mandible has 3 cusps, the lowermost one of which arises from behind the other two (fig. 13). There are 2 points on the distal end of the fifth foot and another point a short distance back of the distal end (fig. 14). The right posterior thoracic margin of the male ends in a hooked spine-like point (fig. 1) and there is a curved, pointed protrusion from the right side of the genital segment (fig. 2). The chela of the fifth foot is also diagnostic (fig. 3).

Candacia bipinnata (Giesbrecht, 1889)

(PLATE 31, FIGS. 4–7)

Synonymy:

Candacia bipinnata (Giesbrecht, 1889, Atti Acc. Lincei Rend., ser. 4, 5 sem. 1: 815).

Candacia pectinata (not of Brady, 1878) Esterly (1905, Univ. Calif. Publ. Zool., 2(4): 193); Mori (1937, The pelagic Copepoda from the neighboring waters of Japan, p. 83); Dakin and Colefax (1940, Publ. Univ. Sydney Dept. Zool. Monogr. 1, p. 105). (*C. pectinata* Brady, 1878=*C. armata* Boeck, 1873.)

Pacific records: Esterly, 1905; Scott, 1909; Tanaka, 1929; Yamada, 1933; Tanaka, 1935b; Mori, 1937; Dakin and Colefax, 1940; Johnson, 1942; Wilson, 1942; Davis, 1949; Motoda, Iizuka, and Anraku, 1950; Brodsky, 1950; Wilson, 1950; Anraku, 1952; Honjo, 1952; Anraku, 1953; Tanaka, 1953; Anraku, 1954b; Chiba, Tsuruta, and Maéda, 1955; Motoda and Anraku, 1955; Nagaya et al., 1955; Chiba, 1956; Honjo et al., 1957;

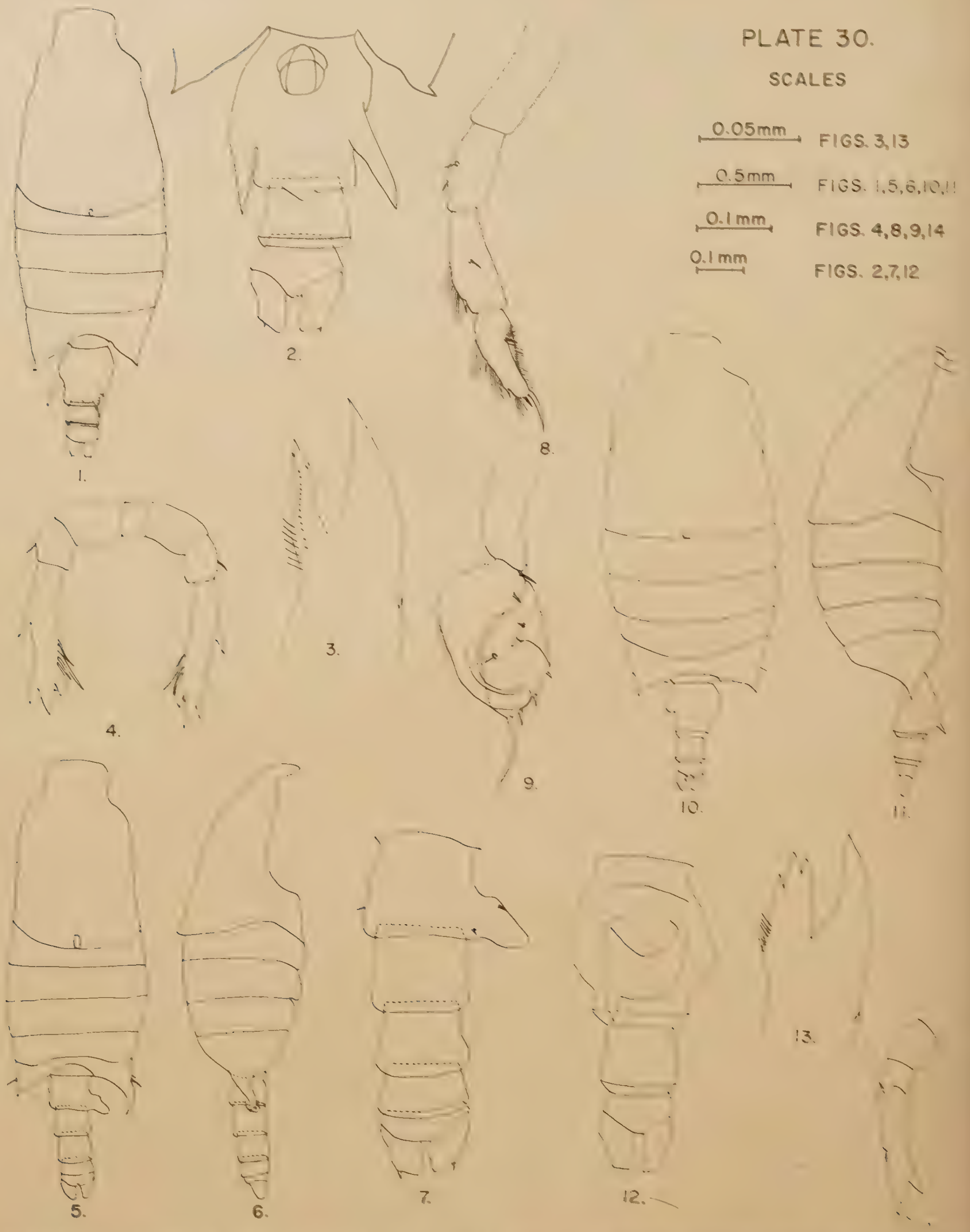


PLATE 30.
SCALES
0.05mm FIGS. 3,13
0.5mm FIGS. 1,5,6,10,11
0.1mm FIGS. 4,8,9,14
0.1mm FIGS. 2,7,12
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.

PLATE 30.—(1) *Candacia pachydactyla*, female, dorsal view; (2) abdomen, ventral view; (3) gnathal lobe mandible; (4) fifth pair of feet; (5) male, dorsal view; (6) lateral view; (7) abdomen, dorsal view; (8) left fift foot; (9) right fifth foot; (10) *C. curta*, female, dorsal view; (11) lateral view; (12) abdomen, ventral view (13) gnathal lobe of mandible; (14) fifth foot.

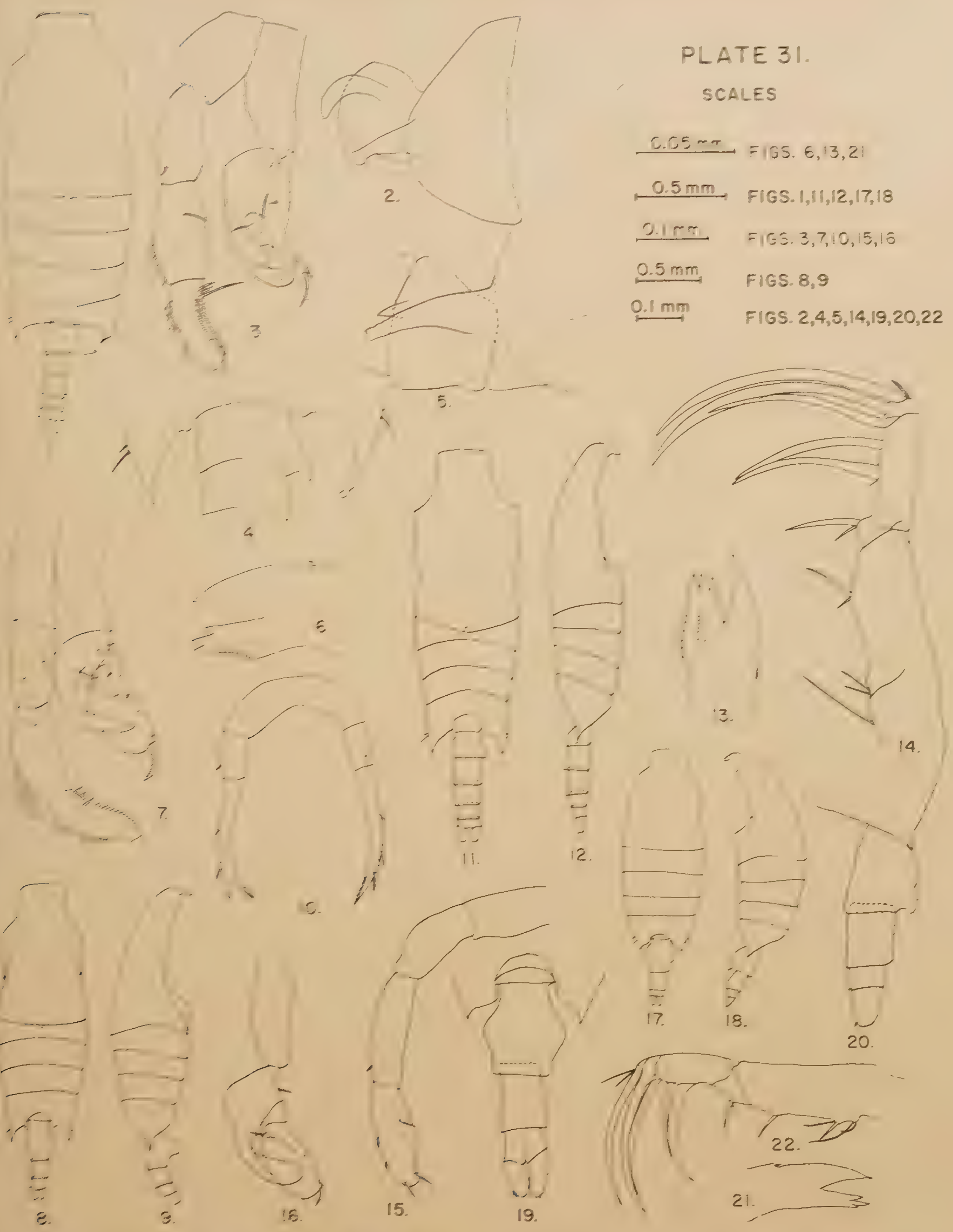


PLATE 31.
SCALES
0.05 mm FIGS. 6,13,21
0.5 mm FIGS. 1,11,12,17,18
0.1 mm FIGS. 3,7,10,15,16
0.5 mm FIGS. 8,9
0.1 mm FIGS. 2,4,5,14,19,20,22
2.
3
5.
4
6
7.
10.
11.
12.
13.
14.
17.
18.
20.
22.
21.
8.
9.
16.
15.
19.

PLATE 31.—(1) *Candacia curta*, male, dorsal view; (2) posterior part of thorax and genital segment, right side;) fifth pair of feet; (4) *C. bipinnata*, male, posterior part of thorax and abdomen, dorsal view; (5) posterior rt of thorax and abdomen, right side; (6) gnathal lobe of mandible; (7) fifth pair of feet; (8) *C. varicans*, nale, dorsal view; (9) lateral view; (10) fifth pair of feet; (11) male, dorsal view; (12) lateral view; 3) gnathal lobe of mandible; (14) second maxilla; (15) left foot; (16) right foot; (17) *C. catula*, female, dorsal ew; (18) lateral view; (19) abdomen, dorsal view; (20) abdomen, lateral view; (21) gnathal lobe of mandible; 2) second maxilla.

Yamazi, 1958a; Brodsky, 1959; Lindberg, 1959. As *C. bipunctata* [=*C. bipinnata*?]; Yamazi, 1953a.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	178	1 male, 1.90 mm.
Do	144	1 male, 2.28 mm.

Remarks: Only two males of this species were found. The right posterior lateral protrusion of the thorax is characteristic. This protrusion exceeds the end of the genital segment and its tip, as seen in dorsal view, is irregular (fig. 4). In lateral view the distal end appears to be somewhat truncate (fig. 5). A small, posteriorly directed hook arises from the right side of the genital segment (fig. 4). The basal tooth of the gnathal lobe of the mandible is tricuspate (fig. 6). The thumb of the chela of the right fifth foot has a stout spine at its tip.

In regard to the above indicated synonymy, Sars (1903) redescribed *C. armata* (Boeck, 1873) and pointed out that *C. pectinata* (Brady, 1878) is a synonym of the former species. *C. armata* is a north Atlantic species which occurs along the east coast of the United States as far south as off Beaufort, North Carolina (Fleminger and Bowman, 1956), and along the coast of Europe probably as far south as off Spain. It has also been reported from the Mediterranean Sea (Rose, 1934) and from the Adriatic Sea (Hure, 1955).

I have examined specimens identified by Esterly (1905) and labeled *C. bipinnata* ♀, *C. pectinata* ♂, which were loaned to me by Dr. Abraham Fleminger of the Scripps Institution of Oceanography. Included in the vial were two females, *C. bipinnata*. Esterly's figure of the fifth foot of his female *C. pectinata* is probably that of a stage V female *C. bipinnata*, a species which also occurred in his collections. The figure of the genital segment of his male *C. pectinata* is clearly referable to *C. bipinnata*. Esterly stated in regard to *C. bipinnata* that he did not find the male of this species.

Mori (1937) reported only the male of *C. pectinata* from Japanese waters. His figures and description of this species indicate that it is actually *C. bipinnata*. The protrusion of the right posterior lateral margin of the thorax, the form of the hook on the right side of the genital segment, and the structure of the fifth
pair of feet all agree with those of *C. bipinnat*
Mori also presented figures of male *C. bipinna*
which are not unlike those of his *C. pectinat*

Dakin and Colefax's (1940) *C. pectina*
(both sexes) which were questionably referre
to this species are also *C. bipinnata.* I ha
examined specimens which were obtained fro
the east coast of Australia and which are sim
lar to the figures presented by these autho
for *C. pectinata.* These copepods are stage
female and adult male *C. bipinnata.*

As to other reports of *C. pectinata* from th
Pacific Ocean, Scott (1909) has previous
stated that Brady's (1883) figures of this sp
cies "represents at least four distinct specie
none of which are identical with it" (*C. pect*
nata=*C. armata*). *C. pectinata* has also bee
reported by Honjo (1952) and Honjo et a
(1957). As the species is included in list
without descriptions or figures, these record
too are questionable and in need of confirma
tion.

Candacia varicans (Giesbrecht, 1892)

(PLATE 31, FIGS. 8–16)

Pacific records: Farran, 1929; Johnson, 1942; Wi
son, 1942; 1950.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	31	2 males, 2.14, 2.18 mm.
Do	63	1 female, 2.55 mm.; 2 males, 2.26, 2.28 mm.

Remarks: The female has a long and sym
metrical genital segment (fig. 8) which is pro
duced on the ventral side (fig. 9). The fift
feet are slightly asymmetrical and terminat
in two rather long, but unequal, points (fig
10). The thorax and genital segment of th
male are symmetrical (figs. 11, 12). The basa
tooth of the mandible ends in three approximately equal cusps. The right fifth foot i
chelate (fig. 16).

Candacia catula (Giesbrecht, 1889)

(PLATE 31, FIGS. 17–22; PLATE 32, FIGS. 1–6)

Pacific records: Scott, 1909; Tanaka, 1935b; Farran
1936; Mori, 1937; Dakin and Colefax, 1940; Mori
1942; Wilson, 1942; Anraku, 1952; Tanaka, 1953

uruta and Chiba, 1954b; Chiba, Tsuruta, and Maéda, 5; Nagaya et al., 1955; Yamazi, 1958a.

ssel;	Station	Occurrence
Hugh M. Smith	178	present.
Do	63	2 females, 1.56, 1.63 mm.; 2 males, 1.46, 1.53 mm.
Stranger	34	7 females, 1.60–1.67 mm.; 2 males, 1.53, 1.62 mm.
Orsom	10	1 female, 1.53 mm.; 1 male, 1.43 mm.
Horizon	32	1 female, 1.59 mm.

Remarks: This is a small species, the females which have a symmetrical genital segment gs. 17, 19). The ventral surface is produced o a lobe (figs. 18, 20). The basal tooth of mandible ends in 3 cusps, the lowermost e of which is quite small (fig. 21). The fifth ot terminates in 3 unequal points (fig. 1). e male posterior thoracic margins are sym- trical (figs. 2, 4) and the chela of the right h foot is small. The thumb of the chela has ong spine protruding from its tip (fig. 6).

Candacia bispinosa (Claus, 1863)

(PLATE 32, FIGS. 7–14)

acific records: Scott, 1909; Farran, 1929; Tanaka, 5b; Farran, 1936; Mori, 1937; Johnson, 1942; Wil- h, 1942; 1950; Honjo, 1952; Tanaka, 1953; Anraku, 4b; Tsuruta and Chiba, 1954b; Chiba, Tsuruta, d Maéda, 1955; Motoda and Anraku, 1955; Nagaya al., 1955; Chiba, 1956; Heinrich, 1957b; Honjo et al., 7; Heinrich, 1958a; Yamazi, 1958a.

ssel:	Station	Occurrence
Hugh M. Smith	153	3 females, 1.66–1.80 mm.
Do	178	1 female, 1.60 mm.
Stranger	34	1 female, 1.67 mm.; 1 male, 1.73 mm.
Orsom	10	1 female, 1.56 mm.; 1 male, 1.56 mm.
Satsuma	32	1 male, 1.70 mm.

Remarks: This species and the following two ecies, *C. simplex* (Giesbrecht) and *C. trun- ta* (Dana), differ in a few details (e.g., struc- re of right, first antenna in male and fifth et in both sexes) from the preceding nine ecies. It has been suggested by Sars (1903) at these three may have to be removed from e genus *Candacia*.

The female of *C. bispinosa* has two spine-like protrusions arising from the genital segment (fig. 7). These protrusions, particularly the one on the left side, are quite variable in shape and in size. In one specimen (*Smith* 178) the left protrusion reaches nearly to the anal segment. There is a small rounded knob arising from the ventral side of the genital segment near the posterior end (fig. 8). The pre-anal segment is asymmetrical. The left side is dilated near the anterior end, but there is some variation in the size of the protrusion. The ventral surface of this segment may or may not have a row of hairs arising from near the posterior end. The basal tooth of the mandible is undivided, but one or more spine-like processes are present on this tooth (fig. 9). The large terminal finger-like protrusion of the distal segment of the fifth foot is finely serrate on both sides (fig. 12).

Segment 20 of the right first antenna of the male is swollen distally (fig. 13). There are 3 outer edge spines on the distal segment of the right fifth foot (fig. 14). The proximal spine is shorter than the distal two spines. The penultimate segment of the left fifth foot is enlarged and the outer edge seta of the distal segment is shorter than the terminal ones.

Candacia simplex (Giesbrecht, 1889)

(PLATE 32, FIGS. 15–18; PLATE 33, FIGS. 1–5)

Pacific records: Scott, 1909; Farran, 1929; 1936; Mori, 1937; Johnson, 1942; Mori, 1942; Wilson, 1942; 1950; Tanaka, 1953; Tsuruta and Chiba, 1954b; Chiba, Tsuruta, and Maéda, 1955; Nagaya et al., 1955; Rose, 1955; Chiba, 1956.

Vessel:	Station	Occurrence
Hugh M. Smith	94	1 female, 1.93 mm.
Do	132	8 females, 1.73–1.87 mm.; 3 males 1.73–1.83 mm.
Do	144	present.
Do	153	1 female, 1.67 mm.
Do	178	2 females, 1.90 mm.; 1 male, 1.80 mm.

Remarks: The genital segment of the female is slightly asymmetrical and has a group of small hair-like structures which are visible on the right side (figs. 15, 16). The terminal finger of the distal segment of the fifth foot is

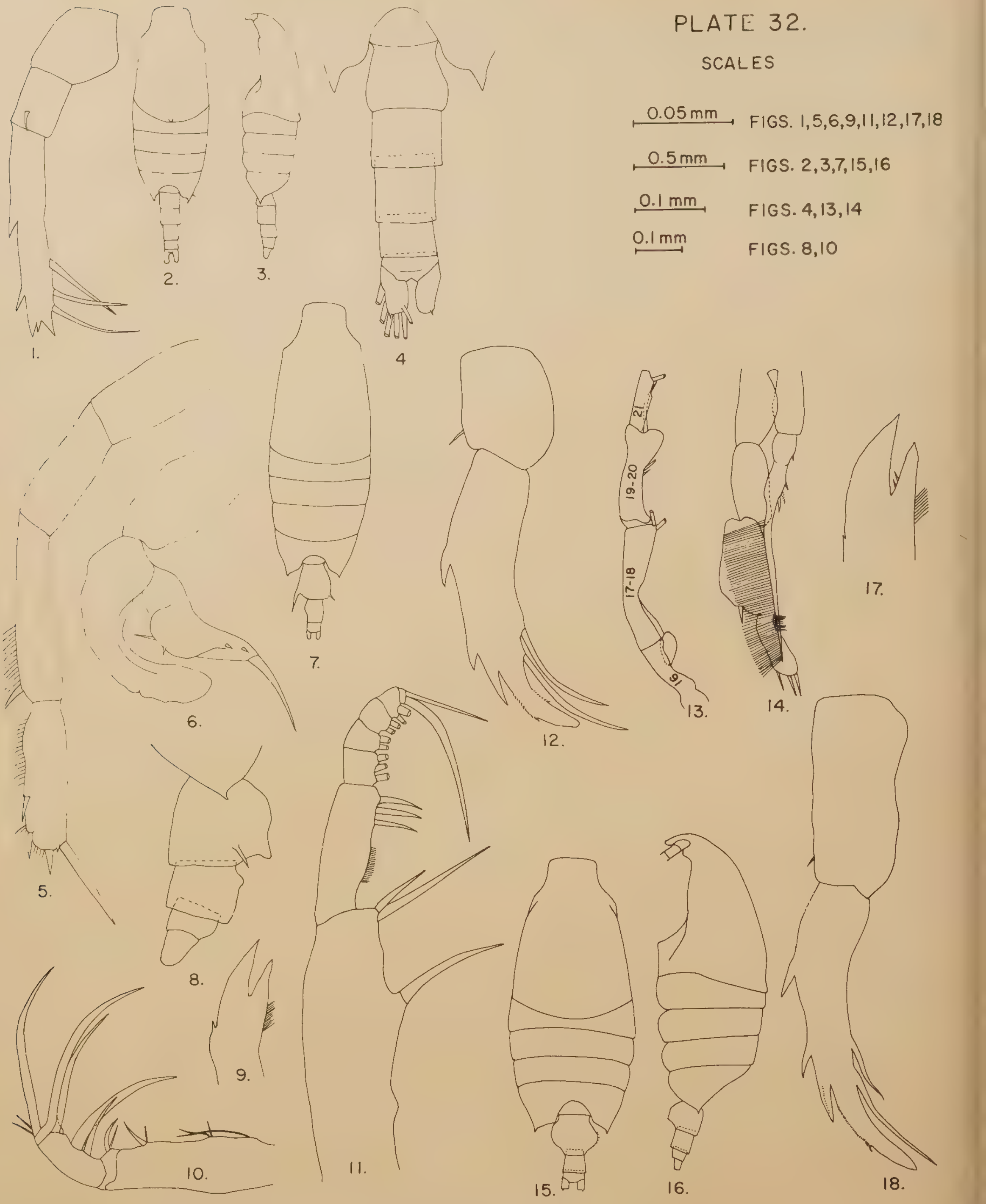


PLATE 32.
SCALES
0.05 mm FIGS. 1,5,6,9,11,12,17,18
0.5 mm FIGS. 2,3,7,15,16
0.1 mm FIGS. 4,13,14
0.1 mm FIGS. 8,10
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.
21
19-20
17-18
16

PLATE 32.—(1) *Candacia catula,* female, fifth foot; (2) male, dorsal view; (3) lateral view; (4) abdome dorsal view; (5) left fifth foot; (6) right fifth foot; (7) *C. bispinosa,* female, dorsal view; (8) abdomen, rig side; (9) gnathal lobe of mandible; (10) second maxilla; (11) maxilliped; (12) fifth foot; (13) male, segmen 16 to 21 of right first antenna; (14) fifth pair of feet; (15) *C. simplex,* female, dorsal view; (16) lateral view (17) gnathal lobe of mandible; (18) fifth foot.

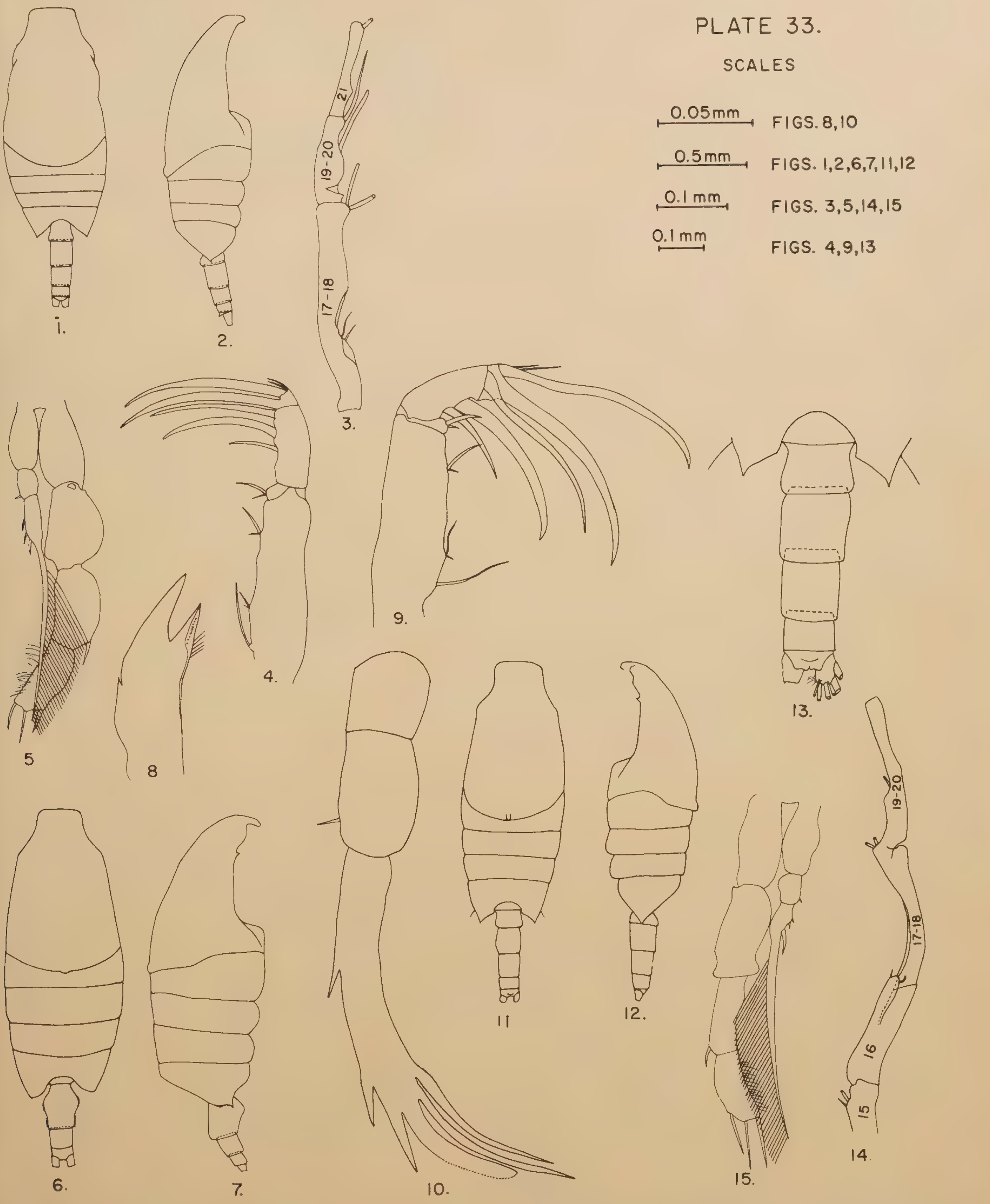


PLATE 33.
SCALES
0.05mm FIGS. 8,10
0.5mm FIGS. 1,2,6,7,11,12
0.1 mm FIGS. 3,5,14,15
0.1 mm FIGS. 4,9,13
1.
2.
21
19-20
17-18
3.
4.
5
8
9.
13.
6.
7.
10.
11
12.
15.
19-20
17-18
16
15
14.

PLATE 33.—(1) *Candacia simplex*, male, dorsal view; (2) lateral view; (3) segments 17 to 21 of right first enna; (4) second maxilla; (5) fifth pair of feet; (6) *C. truncata*, female, dorsal view; (7) lateral view; gnathal lobe of mandible; (9) second maxilla; (10) fifth foot; (11) male, dorsal view; (12) lateral view; 3) abdomen, dorsal view; (14) segments 15 to 20 of right first antenna; (15) fifth pair of feet.

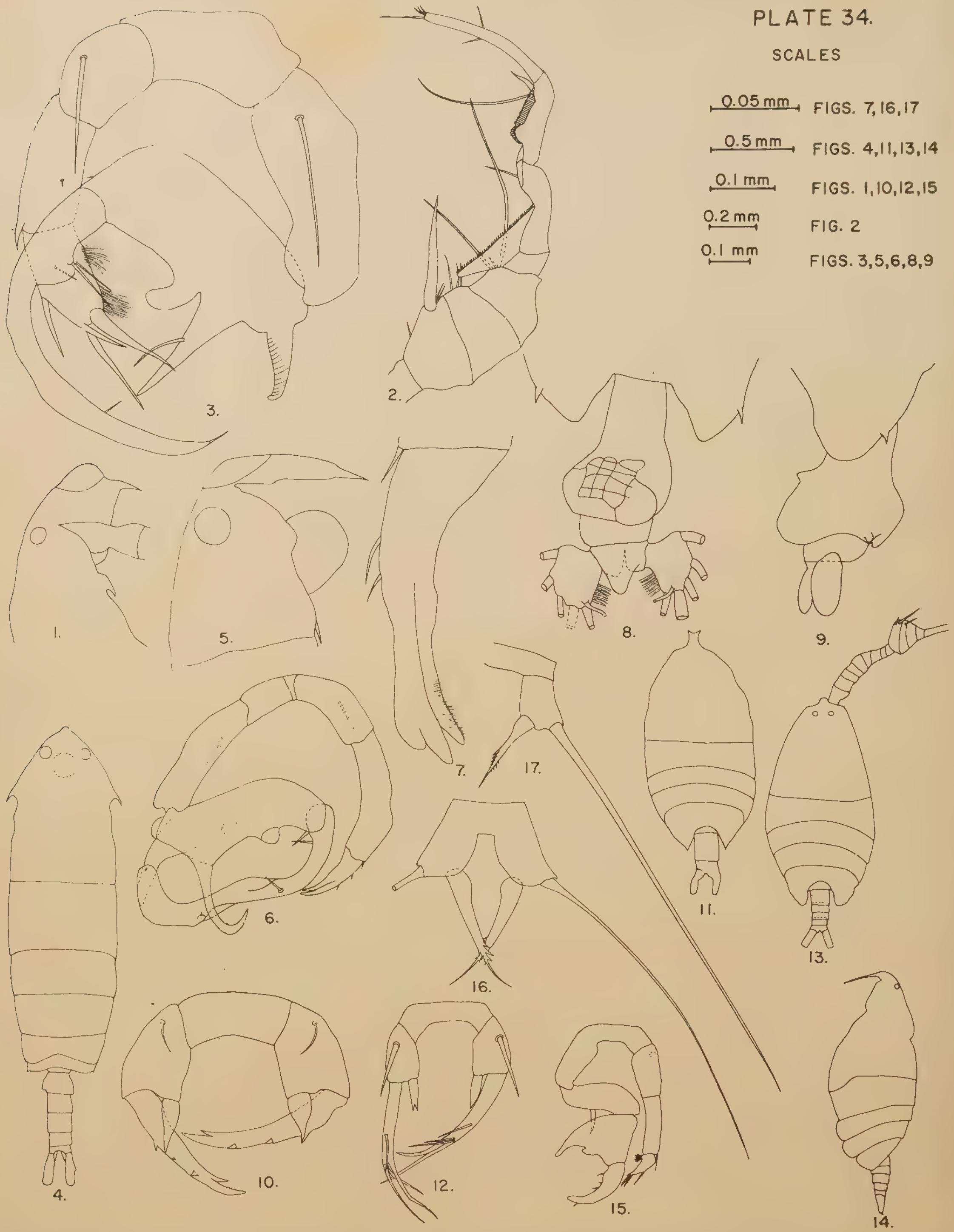


PLATE 34.
SCALES
0.05 mm FIGS. 7, 16, 17
0.5 mm FIGS. 4, 11, 13, 14
0.1 mm FIGS. 1, 10, 12, 15
0.2 mm FIG. 2
0.1 mm FIGS. 3, 5, 6, 8, 9
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.

PLATE 34.—(1) *Pontella securifer*, male, forehead, lateral view; (2) distal end of right first antenna; (3) fift pair of feet; (4) *P. tenuiremis*, male, dorsal view; (5) forehead, lateral view; (6) fifth pair of feet; (7) left fift foot; (8) *Labidocera detruncata*, female, abdomen, dorsal view; (9) lateral view; (10) fifth pair of feet; (11) *Pon* *tellina plumata*, female, dorsal view; (12) fifth pair of feet; (13) male, dorsal view; (14) lateral view; (15) fift pair of feet; (16) *Acartia danae*, female, fifth foot; (17) *A. negligens*, female, fifth pair of feet.

ly serrate on the external margin (fig. 18). the 2 internal setae on this segment, the tal one is approximately twice the length of proximal one. The male thorax and ab-nen are symmetrical (figs. 1, 2). The right h foot is similar to that of *C. bispinosa* (fig. The left fifth foot terminates in 3 setae, middle one of which is the longer. The ultimate segment is not particularly en-ged.

Candacia truncata (Dana, 1849)

(PLATE 33, FIGS. 6–14)

acific records: Scott, 1909; Yamada, 1933a; Ta-a, 1935b; Farran, 1936; Mori, 1937; Dakin and efax, 1940; Mori, 1942; Wilson, 1942; Tanaka, 1953; aku, 1954b; Tsuruta and Chiba, 1954b; Chiba, Tsu-, and Maéda, 1955; Motoda and Anraku, 1955; aya et al., 1955; Chiba, 1956; Heinrich, 1957b; jo et al., 1957; Yamazi, 1958a; 1958b; Grice and es, 1960. As *C. turgida;* Wilson, 1950.

sel:	*Station*	*Occurrence*
Hugh M. Smith	132	3 females, 1.90–2.00 mm.; 2 males, 2.11 mm.
Do	153	3 males, 1.97–2.11 mm.
Do	30	present.
Do	63	1 female, 1.87 mm.
Vessel:	*Station*	*Occurrence*
Stranger	34	7 females, 1.94–2.04 mm.; 3 males, 1.94–1.97 mm.
Orsom	10	3 females, 1.97–2.04 mm.; 1 male, 2.06 mm.
Horizon	32	11 females, 1.84–2.00 mm.; 5 males, 1.94–2.00 mm.
Satsuma	32	5 females, 1.87–1.90 mm.; 3 males, 1.87–2.00 mm.

Remarks: The female genital segment is symmetrical and finely pubescent on the lateral margins (fig. 16). The terminal finger of the distal segment of the fifth foot is finely serrate along its outer distal margin (fig. 10). The proximal seta on the internal margin is slightly shorter than the distal one. The male thorax and abdomen are symmetrical (figs. 11, 12). Segment 16 of the right first antenna is produced into an elongate process (fig. 14). The distal spine on the terminal segment of the right fifth foot (fig. 15) is considerably larger than the preceding two spines. The terminal seta on some specimens is articulated to this segment while in others it is not.

Family PONTELLIDAE

Pontella securifer Brady, 1883

(PLATE 34, FIGS. 1–3)

acific records: Scott, 1909; Farran, 1936; Dakin Colefax, 1940; Wilson, 1942; 1950; Tanaka, 1953.

sel:	*Station*	*Occurrence*
Hugh M. Smith	30	2 females, 4.40, 4.46 mm.
Do	31	1 male, 4.40 mm.

Remarks: Both sexes have a large lens sit-ed at the base of the rostrum. Figures of male sex are given (figs. 1–3).

Pontella tenuiremis Giesbrecht, 1889

(PLATE 34, FIGS. 4–7)

acific records: Wilson, 1942; 1950.

sel:	*Station*	*Occurrence*
Horizon	32	1 male, 2.80 mm.

Remarks: The structure of the fifth feet (figs. 6, 7) distinguishes the male of this species from other *Pontella*. No females were found.

Labidocera detruncata (Dana, 1849)

(PLATE 34, FIGS. 8–10)

Pacific records: Scott, 1909; Yamada, 1933; Farran, 1936; Mori, 1937; Dakin and Colefax, 1940; Mori, 1942; 1950; Tanaka, 1953; Anraku, 1954b; Chiba, Tsuruta, and Maéda, 1955; Nagaya et al., 1955; Chiba, 1956; Yamazi, 1958a; 1958b.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	30	1 female, 2.72 mm.
Do	32	1 female, 2.68 mm.

Remarks: The lateral margins of the last thoracic segment (figs. 8, 9) are pointed and the genital segment is asymmetrical. These two characters plus the structure of the fifth feet (fig. 10) will identify the female. No male was found in the present collections.

Pontellina plumata (Dana, 1849)

(PLATE 34, FIGS. 11–15)

Pacific records: Scott, 1909; Farran, 1929; 1936; Mori, 1937; Dakin and Colefax, 1940; Mori, 1942; Wilson, 1950; Anraku, 1952; Tanaka, 1953; Anraku, 1954b; Tsuruta and Chiba, 1954b; Chiba, Tsuruta, and Maéda, 1955; Motoda and Anraku, 1955; Nagaya et al., 1955; Chiba, 1956; Heinrich, 1958a; Yamazi, 1958a.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	132	1 female, 1.66 mm.; 2 males, 1.49, 1.59 mm.
Do	178	present.
Do	30	9 females, 1.43–1.8 mm.; 1 male, 1 mm.
Do	31	2 females, 1.62, 1.8 mm.
Do	63	present.
Stranger	34	2 females, 1.56, 1.6 mm.
Orsom	10	present.
Horizon	32	present.

Remarks: The female is distinguished the symmetrically pointed posterior margins the last thoracic segment (fig. 11) and t right furca. This furca is fused to the an segment. The posterior lateral margins of t last thoracic segment of the male are round (figs. 13, 14) and the right fifth foot is chela (fig. 15).

Family ACARTIIDAE

Acartia danae Giesbrecht, 1889

(PLATE 34, FIG. 16)

Pacific records: Scott, 1909; Farran, 1929; 1936; Mori, 1937; Dakin and Colefax, 1940; Johnson, 1942; Mori, 1942; Wilson, 1942; Davis, 1949; Wilson, 1950; Anraku, 1952; Tanaka, 1953; Anraku, 1954b; Motoda and Anraku, 1955; Heinrich, 1957b; Honjo et al., 1957; Heinrich, 1958a; Yamazi, 1958a; 1958b.

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	94	present.
Do	132	1 female, 1.12 mm.
Do	178	present.

Remarks: The female has a large spine on the first segment of the first antennae and the posterior lateral margins of the thorax end in a large point. The external seta on the fifth foot (fig. 16) is slightly more than twice the length of the internal spine.

Acartia negligens Dana, 1849

(PLATE 34, FIG. 17)

Pacific records: Scott, 1909; Farran, 1929; 1936; Mori, 1937; 1942; Wilson, 1942; 1950; Anraku, 1952; Honjo, 1952; Tanaka, 1953; Anraku, 1954b; Tsuru and Chiba, 1954b; Chiba, Tsuruta, and Maéda, 195 Motoda and Anraku, 1955; Nagaya et al., 1955; Chib 1956; Heinrich, 1957b; 1958a; Yamazi, 1958a; 1958

Vessel:	*Station*	*Occurrence*
Hugh M. Smith	153	2 females, 1.05, 1 mm.
Do	178	present.
Do	30	10 females, 1.08–1.2 mm.
Do	31	5 females, 1.10–1.1 mm.
Do	63	present.
Stranger	34	2 females, 1.08, 1.1 mm.
Orsom	10	14 females, 1.10–1.1 mm.
Satsuma	32	present.

Remarks: In contradistinction to *A. dana* the posterior lateral margins of the last thorac segment have a series of very small point The external seta on the fifth foot (fig. 17) more than four times the length of the intern spine.

LITERATURE CITED

ku, M.

952. Plankton copepods collected by R. S. *Yushino-Maru* in Pacific waters to the east of northern Japan during her cruise in November, 1948. Bulletin of the Faculty of Fisheries. Hokkaido University 3(1): 31–39. [In Japanese.]

953. Seasonal distribution of pelagic copepods at Oshora Bay, west coast of Hokkaido. Bulletin of the Faculty of Fisheries. Hokkaido University 3(3): 187–192.

954a. Distribution of plankton copepods off Kitami, Hokkaido, in Okhotsk Sea in summer, 1949 and 1950. Bulletin of the Faculty of Fisheries. Hokkaido University 4(4): 249–255.

954b. Copepods collected on the whaling grounds off northern Japan and Bonin Islands. Bulletin of the Faculty of Fisheries. Hokkaido University 5(1): 1–8.

954c. Gymnoplea Copepoda collected in Aleutian waters in 1953. Bulletin of the Faculty of Fisheries. Hokkaido University 5(2): 123–136.

in, T. S.

1957. Summary, oceanographic and fishery data, Marquesas Islands area, August-September, 1956 (Equapac). U.S. Fish and Wildlife Service, Special Scientific Report—Fisheries No. 217, 186 p.

, B. M.

1959. Species of zooplankton as a means of identifying different surface waters and demonstrating their movements and mixing. Pacific Science 13(1): 14–54.

ard, M.

1958. Révision des *Calocalanus* (Copépodes Calanoida) avec description d'un genre nouveau et deux espèces nouvelles. Bulletin de la Société zoologique de France 83(2–3): 185–199.

k, A.

1873. Nye slaegter og arter af saltvands-copepoder. Christiania Videnskabs-Selskabet Forhanlinger, p. 37–60.

man, T. E.

1955. A new copepod of the genus *Calanus* from the northeastern Pacific with notes on *Calanus tenuicornis* Dana. Pacific Science 9(4): 413–422.

1958. A new species of *Acrocalanus* (Copepoda: Calanoida) from off the southeastern coast of the United States. Bulletin of Marine Science of the Gulf and Caribbean 8(2): 118–124.

dy, G. S.

1878. A monograph of the free and semi-parasitic Copepoda of the British Islands. Vol. 1. The Ray Society, p. 1–148.

1883. Report on the Copepoda collected by *H.M.S. Challenger* during the years 1873–76. Report on the Scientific Results of *HMS Challenger*, Zoology. Vol. 8, p. 1–142.

1899. On the marine Copepoda of New Zealand. Transactions of the Zoological Society of London 15, pt. 2:31–54.

Brodsky, K. A.

1950. Calanoida of polar and far eastern seas of the U.S.S.R. Opredeliteli po Fauna S.S.S.R., Izdavaemi, Zoologicheskim Institutom Akademii Nauk SSSR. 35: 1–442. [In Russian.]

1952. On the vertical distribution of copepods in the northwestern Pacific Ocean. Investigations of the far eastern seas of the U.S.S.R. *III.* Deep water fauna of the northwestern Pacific Ocean, p. 88–94. [Translated by W. G. Van Campen, 1956, U.S. Fish and Wildlife Service, Special Scientific Report—Fisheries No. 192, p. 1–6.]

1955. Plankton of the northwestern part of the Kuroshio and waters of the Pacific Ocean adjacent to the Kurile Islands. Transactions of the Institute of Oceanology, Academy of Sciences, U.S.S.R. 18: 124–133. [Translated by W. G. Van Campen, 1956, U.S. Fish and Wildlife Service, Special Scientific Report—Fisheries No. 192, p. 16–24.]

1959. Zooplankton of sea waters of south Sakhalin and south Kurile Islands. Investigations of Far Eastern Seas VI, Academy of Sciences, U.S.S.R., p. 5–46. [In Russian.]

Campbell, M. H.

1929. Some free swimming copepods of the Vancouver Island region. Transactions of the Royal Society of Canada 23, pt. 2, sect. 5: 303–332.

Chiba, T.

1949. On the distribution of the plankton in the eastern China Sea and Yellow Sea. I. Plankton composition in spring. The Journal of the Shimonoseki College of Fisheries 1(1): 57–63. [In Japanese.]

1952a. On the distribution of the plankton in the eastern China Sea and Yellow Sea. II. Observation on the plankton in spring during the period 1949–50. Bulletin of the Japanese Society of Scientific Fisheries 17(7): 183–186. [In Japanese.]

1952b. On the distribution of the plankton in the eastern China Sea and Yellow Sea. III. Observations on the plankton in autumn during the years 1948–1949. Bulletin of the Japanese Society of Scientific Fisheries 17(7): 187–190. [In Japanese.]

1952c. On the plankton of Nakano-Umi in summer, 1948. The Journal of the Shimonoseki College of Fisheries 2(1): 48–53. [In Japanese.]

1953a. Some observations on the morphological characteristics especially on the reproductive organ of Copepoda, *Calanus darwini.* The Journal of the Shimonoseki College of Fisheries 3(3): 235–238. [In Japanese.]

1953b. Studies on the pelagic Copepoda from the Japan Sea. 1. On the genus *Euchaeta* Philippi, 1843. Bulletin of the Japanese Society of Scientific Fisheries 18(11): 613–617.

1956. Studies on the development and the systematics of Copepoda. The Journal of the Shimonoseki College of Fisheries 6(1): 1–90. [In Japanese.]

CHIBA, T., A. TSURUTA, and H. MAÉDA.

1955. Report on zooplankton samples hauled by larva-net during the cruise of Bikini expedition, with special reference to copepods. The Journal of the Shimonoseki College of Fisheries 5(3): 189–213.

DAKIN, W. J., and A. N. COLEFAX.

1940. The plankton of the Australian coastal waters off New South Wales. Pt. 1. Publications of the University of Sydney, Department of Zoology Monograph 1, p. 1–211.

DAVIS, C. C.

1949. Pelagic Copepoda of the northeastern Pacific Ocean. University of Washington Publications in Zoology. Vol. 14, 117 p.

ESTERLY, C. O.

1905. The pelagic Copepoda of the San Diego region. University of California Publications in Zoology 2(4): 113–233.

1906. Additions to the copepod fauna of the San Diego region. University of California Publications in Zoology 3(5): 53–92.

1911. Third report on the Copepoda of the San Diego region. University of California Publications in Zoology 6(14): 313–352.

1913. Fourth taxonomic report on the Copepoda of the San Diego region. University of California Publications in Zoology 11(10): 181–196.

1924. The free swimming Copepoda of San Francisco Bay. University of California Publications in Zoology 26(5): 81–129.

FARRAN, G. P.

1929. Crustacea. Part X. Copepoda. British Antarctic (*Terra Nova*) Expedition, 1910, Natural History Report, Zoology 8(3): 203–306.

1936. Copepoda. Great Barrier Reef Expedition 1928–29. Scientific Reports 5(3): 73–142.

FLEMINGER, A.

1956. Taxonomic and distributional studies on the epiplanktonic calanoid copepods (Crustacea) of the Gulf of Mexico. Doctoral Dissertation, Harvard University Library.

FLEMINGER, A., and T. E. BOWMAN.

1956. A new species of *Candacia* (Copepoda: Calanoida) from the western north Atlantic Ocean. Proceedings of the U.S. National Museum 106(3370): 331–337.

FUKASE, S.

1957. Note on a variety of *Eucalanus subtenuis* Giesbrecht from the Japanese waters. Journal of the Oceanographical Society of Japan 13(1): 17–21.

GIESBRECHT, W.

1888, 1889, 1891. Elenco dei copepodi pela
raccolti dal tenente di vascello Gaetano Chier
durante il viaggio della R. Corvetta *Vettor Pis*
negli anni 1882–1885 e dal tenente di vasc
Francesco Orsini nel Mar Rosso, nel 1884.
della R. Accademia Nazionale dei Lincei Re
conti, (4). Vol. 4, sem. 2 (1888): 284–
330–338. Vol. 5 (1889), sem. 1: 811–815; s
2: 24–29. Vol. 7 (1891), sem. 1: 474–481; s
2: 63–68, 276–282.

1892. Systematik und faunistik der pelagisc
Copepoden des Golfes von Neapel. Fauna
Flora des Golfes von Neapel u. d. angrenz Mee
abschnitte 19: 1–831.

1895. Die pelagischen Copepoden. Bulletin of
Museum of Comparative Zoology at Harv
College 25(12): 243–263.

1896. Ueber pelagische Copepoden des Rot
Meeres gesammelt vom marinestabsarzt
Augustin Krämer. Zoologische Jahrbucher, A
Systematik. Vol. 9, p. 315–327.

GIESBRECHT, W., and O. SCHMEIL.

1898. Copepoda I. Gymnoplea. Das Tierrei
Lief. 6, 169 p.

GILMARTIN, M.

1958. Some observations on the lagoon plankt
of Eniwetok Atoll. Pacific Science 12(4): 31
316.

GRICE, G. D.

1959. A new species of *Haloptilus* (Copepod
Calanoida) from equatorial and subtropi
waters of the east-central Pacific Ocean. Jou
nal of the Washington Academy of Scienc
49(6): 193–195.

GRICE, G. D., and E. C. JONES.

1960. Two new species of *Candacia* (Copepod
Calanoida) from the central Pacific with not
on two other species. Pacific Science 14(3
280–291.

HEINRICH, A. K.

1957a. The distribution of *Calanus tenuicorn*
Dana and *Calanus lighti* Bowman in the nor
Pacific. Doklady Akademii Nauk S.S.S.R. 1
(4): 691–693 [In Russian.]

1957b. The vertical distribution of the plankt
to the southeast from the Bonin Islands. Doklad
Akademii Nauk S.S.S.R. 117(2): 321–324. [
Russian.]

1958a. The vertical distribution of copepods
the Kuroshio Current and the way they pen-
trate into the zone of mixing of subtropical a
subarctic waters. Doklady Akademii Na
S.S.S.R. 118(6): 1191–1193. [In Russian.]

1958b. On the feeding of copepods in the tropic
region. Doklady Akademii Nauk S.S.S.R. 1
(5): 1028–1031. [In Russian.]

HIDA, T., and J. E. KING.

1955. Vertical distribution of zooplankton in th central equatorial Pacific, July–August 1952. U.S. Fish and Wildlife Service, Special Scientific Report—Fisheries No. 144, 22 p.

o, K.

952. Distribution of Copepoda in the adjacent sea of the Izu Islands during winter and spring. Bulletin of the Tokai Regional Fisheries Research Laboratory, No. 4, p. 1–5. [In Japanese.]

o, K., H. Ohta, T. Kidachi, K. Umeda, and Kudoh.

957. Distribution of Copepoda in the "Kuroshiro" area, south of Honshu, May, 1955. Records of Oceanographic Works in Japan, Special No. March 1957, p. 120–129.

, J.

1955. Distribution annuelle verticale du zooplancton sur une station de l'Adriatique meridionale. Acta Adriatica Institut za Oceanografiju i Ribarstvo–Split fnr Jugoslavija 7(7): p. 1–72.

nese Hydrographic Office.

1956. Plankton observation. Equapac Expedition. Japanese Hydrographic Office. [Unpublished processed report.]

son, M. W.

942. Notes on Zooplankton. Records of Observations, Scripps Institution of Oceanography. Vol. 1, No. 1, Oceanographic Observations on the E. W. Scripps Cruises of 1938, p. 27–29.

949. Zooplankton as an index of water exchange between Bikini Lagoon and the open sea. Transactions of the American Geophysical Union 30(2): 238–244.

1954. Bikini and nearby atolls. Pt. 2. Oceanography (biologic). Plankton of northern Marshall Islands. U.S. Geological Survey, Professional Paper F, p. 301–314.

, J. E., T. S. Austin, and M. S. Doty.

1957. Preliminary report on expedition *Eastropic.* U.S. Fish and Wildlife Service, Special Scientific Report—Fisheries No. 201, 155 p.

uss, J. A.

1959. Direct current measurements at the equator–the Cromwell Current. International Oceanographic Congress, 31 August–12 September 1959. Preprints, American Association for the Advancement of Science, p. 515–516.

uss, J. A., and J. E. King.

1958. Observations of the Pacific equatorial undercurrent. Nature 182 (4635): 601–602.

bo, S.

1950. The ecology of certain Copeda in Japan Sea, and Mutsu Bay. Bulletin of the Japanese Society of Scientific Fisheries 16(5): 215–220. [In Japanese.]

nd, M.

1957. *Orsom III.* Résultats biologiques de l'expédition Equapac. Institut Français d'Océanie, Rapport Scientifique No. 1. [Processed report.]

ré, J. E. H.

1957. The qualitative and quantitative distribution of plankton in the Strait of Georgia in relation to certain oceanographic factors. Journal of the Fisheries Research Board of Canada 14(4): 551–552.

Lindberg, G. U.

1959. A list of the fauna of sea waters of the south Sakhalin and south Kurile Islands. Investigations of Far Eastern Seas. VI. Academy of Sciences of the U.S.S.R., p. 173–256. [In Russian.]

Lowe, C. W.

1936. Observations on some Pacific diatoms as the food of copepods and fishes. Journal of the Biological Board of Canada 3(1): 12–19.

McEwen, G. F., M. W. Johnson, and T. R. Folsom.

1954. A statistical analysis of the performance of the Folsom plankton sample splitter, based upon test observations. Archiv für Meteorologie, Geophysik und Bioklimatologie, Ser. A., 7: 502–527.

McMurrich, J. P.

1916. Notes on the plankton of the B. C. coast. Transactions of the Royal Society of Canada 10, Ser. 3, sect. 5:75–89.

Marukawa, H.

1921. Plankton list and some new species of Copepoda from the northern waters of Japan. Bulletin Institute of Oceanography No. 384.

Mori, T.

1930. An annotated list of the pelagic Copepoda from the S. W. part of the Japan Sea with descriptions of two new species. Zoological Magazine 41(487): 199–209. [In Japanese.]

1932. New copepods from southern Japan. Zoological Magazine, 44(523): 167–177. [In Japanese.]

1937. The pelagic Copepoda from the neighbouring waters of Japan. Tokyo. 150 p.

1942. Systematic studies of the plankton organisms occurring in Iwayama Bay, Palao. IV Copepoda from the Bay and adjacent waters. Palao Tropical Biological Station Studies, 2(3): 549–580.

Motoda, S., and M. Anraku.

1951. An observation on the vertical distribution of plankton at Ishikari Bay, Hokkaido. Journal of the Oceanographic Society of Japan 6(4): 194–201. [In Japanese.]

1952a. Observations on the plankton of Funka Bay, Hokkaido. I. Vertical distribution of plankton at the mouth of the bay in August 1950. Bulletin of the Hokkaido Region Fisheries Laboratory, No. 5, p. 17–20. [In Japanese.]

1952b. Plankton investigations (spring and summer, 1951). Report of the Deep Sea Fisheries of the Northern Japan Sea, No. 3, p. 71–76. [In Japanese.]

1954. Daily change of vertical distribution of plankton animals near western entrance to the Tsugaru Strait, Northern Japan. Bulletin of the

Faculty of Fisheries, Hokkkaido University 5(1): 15–19.

1955. Marine plankton copepods from the Hachijo Island, Idzu Islands, with special reference to their vertical distribution. Records of Oceanographic Works in Japan 2(1): 210–214.

Motoda, S., A. Iizuka, and M. Anraku.

1950. Plankton distribution to the northwest of Hokkaido in summer 1949. Report of the Deep Sea Fisheries of the Northern Japan Sea, No. 1, p. 78–109. [In Japanese.]

Nagaya, Y., Y. Komaki, T. Chiba, A. Tsuruta, and H. Maéda.

1955. Effects of artificial radioactivity on plankton. Publication of the Fishery Agency of Japan, p. 33–54. [In Japanese.]

Nakai, Z.

1952. On quantitative distribution of plankton reproduced in the northern Pacific. Tokai Regional Fisheries Laboratory, Special Publication No. 2, p. 1–6.

1955. The chemical composition, volume, weight, and size of the important marine plankton. Tokai Regional Fisheries Research Laboratory, Special Publication No. 5, p. 12–24.

Ponomareva, L. A.

1959. Some data on the zooplankton of the western coast of the south Sakhalin Island. Investigations of Far Eastern Seas. VI. Academy of Sciences of the U.S.S.R., p. 47–57. [In Russian.]

Rose, M.

1933. Copépodes pélagiques. Faune de France, 26: 1–374.

1934. Recherches complementaires sur les copépodes pélagiques de baie d'Alger. Bulletin de la Société d'histoire naturelle de l'Afrique du Nord 25(5): 145–148.

1942. Les Scolecithricidae (Copépodes pélagiques) de la Baie d'Alger. Annales de l'Institut Océanographique, n. s. 21, Pt. 3: 113–170.

1955. Quelques notes sur le plancton marin recueilli en 1953, par M. G. Ranson, dans la baie de Nhatrang-Canda (Viet Nam). Bull. du Muséum, 2ᵉ serie, vol. 27, No. 5.

Sars, G. O.

1903. Copepoda. Calanoida. Crustacea of Norway, Volume IV. 171 p.

1905. Listes preliminaires de Calanoides recueillis pendant les campagnes de S.A.S. le Prince Albert de Monaco avec diagnoses des genres et des espèces nouvelles. Bulletin du Musée Océanographique de Monaco, No. 26, 22 p.

Schmitt, W. L.

1939. Decapoda and other crustacea collected on the Presidential cruise of 1938. Smithsonian Miscellaneous Collections 98(6): 29 p.

Scott, A.

1909. The Copepoda of the *Siboga* expedition. Pt. 1. Free swimming, littoral and semi-parasitic Copepoda. Siboga-Expéditie Monograph
29a, p. 1–323.

Scott, T.

1894. Report on Entomostraca from the Gulf
Guinea. Transactions of the Linnean Socie
of London, series 2, Zoology. Vol. 6, Pt.
161 p.

Scripps Institution of Oceanography.

1957. Data collected by Scripps Institution ve
sels on Equapac Expedition, August 195
Scripps Institution of Oceanography Data R
port, ref. 57–25. [Processed report.]

Sewell, R. B. S.

1929, 1932. The Copepoda of Indian Seas. Cal
noida. Memoirs of the Indian Museum 10:
221 (1929), 223–407 (1932).

1947. The free swimming planktonic Copepod
Systematic Account. *John Murray* Expeditio
1933–34. Scientific Report 8(1): 1–303.

Shen, Chia-Jui, and Sye-O Bai.

1956. The Marine Copepoda from the spawnin
ground of *Pneumatophorus japonicus* (Hou
tuyn) off Chefoo, China. Acta Zoologica Sini
8(2): 177–234. [In Chinese.]

Steuer, A.

1932. Copepoda 6: *Pleuromamma* Giesbr. 1898 d
Deutschen Tiefsee-Expedition. Wissenschaf
liche Ergebnisse der Deutschen Tiefsee-Exped
tion, 1898–1899, 24(1): 1–119.

Streets, T. H.

1877. Contribution to the natural history of th
Hawaiian and Fanning Islands and lower Cal
fornia. Bulletin, U.S. National Museum, No.
p. 1–172.

Tanaka, O.

1935a. The Copepoda of Sagami Bay. Famil
Eucalanidae I. Suisan Gakkwai Ho (Tokyo
6(3): 142–165. [In Japanese.]

1935b. The Copepods of Sagami Bay. Pt. II. Th
family Candaciidae. Suisan Gakkwai Ho (Tok
yo) 6(4): 210–227. [In Japanese.]

1936. On some new species of Copepoda fro
Sagami Bay. Japanese Journal of Zoology 7(1)
31–36.

1937. Copepods from the deep water of Surug
Bay. Japanese Journal of Zoology 7(2): 251
271.

1953. The pelagic copepods of the Izu regio
Records of Oceanographic Works in Japan 1(1)
126–137.

1956a. The pelagic copepods of the Izu Regio
middle Japan. Systematic Account. I. Fam
lies Calanidae and Eucalanidae. Publication
of the Seto Marine Biological Laboratory 5(2)
251–272.

1956b. The pelagic copepods of the Izu Regio
middle Japan. Systematic Account. II. Fam
lies Paracalanidae and Pseudocalanidae. Publ
cations of the Seto Marine Biological Labor
tory 5(3): 367–406.

57a. The pelagic copepods of the Izu Region, middle Japan. Systematic Account. III. Family Aetideidae (Part 1). Publications of the Seto Marine Biological Laboratory 6(1): 31–68.

57b. The pelagic copepods of the Izu Region, middle Japan. Systematic Account. IV. Family Aetideidae (Pt. 2). Publications of the Seto Marine Biological Laboratory 6(2): 169–207.

58. The pelagic copepods of the Izu Region, middle Japan. Systematic Account. V. Family Euchaetidae. Publications of the Seto Marine Biological Laboratory 6(3): 327–367.

TA, A., and T. CHIBA.

54a. On the distribution of plankton at the fishing ground of salmons in the north Pacific Ocean, 1952. Journal of the Shimonoseki College of Fisheries 3(3): 239–245. [In Japanese.]

54b. On the plankton at the fishing ground of tuna in the mid-Pacific Ocean. (1953.) Journal of the Shimonoseki College of Fisheries 3(3): 247–253. [In Japanese.]

RT, W.

46. Biological results of the *Snellius* Expedition. XV. The bathypelagic Copepoda Calanoida of the *Snellius* Expedition. I. Families Calanidae, Eucalanidae, Paracalanidae, and Pseudocalanidae. Temminckia 8: 1–181.

49. Some new and rare Copepoda Calanoida from east Indian Seas. Zoologische Verhandelingen, No. 5, 53 p.

50. On the identity of *Onchocalanus nudipes* C. B. Wilson, 1942. Proceedings of the Section of Sciences, Koninklijke Nederlandse Akademie van Wetenschappen 53(1): 83–92.

51. Plankton copepods from the Atlantic sector of the Antarctic. Verhandelingen der Koninklijke Nederlandse Akademie van Wetenschappen Afdeeling Natuurkunde, Sect. 2. Vol. 47 (no. 4): 1–156.

52. Copepoda. Sub-order Calanoida. Family Aetideidae, Genus *Euchirella.* Fiches d'Identification du Zooplancton 47. Conseil Permanent International pour l'Exploration de la Mer.

57. Copepods from Antarctic and sub-Antarctic plankton samples. B.A.N.Z. Antarctic Research Expedition 1929–1931. Reports, Ser. B (Zoology and Botany), 160 p.

N, C. B.

42. The copepods of the plankton collected during the last cruise of the *Carnegie.* Carnegie Institution of Washington Publication No. 536, 237 p.

50. Copepods gathered by the U.S. Fisheries steamer *Albatross* from 1887 to 1909, chiefly in the Pacific Ocean. U.S. National Museum Bulletin 100, 14(4): 141–441.

NDEN, R. N.

05. Notes on the collection of Copepoda. The Fauna and Geography of the Maldive and Laccadive Archipelagoes. Vol. 2. Suppl. 1: 989–1040.

YAMADA, T.

1933a. On the distribution of the temperate plankton in the western part of the Korean Strait. Bulletin of the Japanese Society of Scientific Fisheries 1(6): 281–286. [In Japanese.]

1933b. Report on the distribution of the plankton in the neighboring seas of Tyosen in June 1932. Annual Report of the Hydrographic Observatory of the Fishery Experiment Station. Government General of Tyosen, No. 7. Appendix. [In Japanese.]

YAMAZI, I.

1950. Plankton investigations in inlet waters of Japan. I. Introductory notes and the plankton of Akkeshi Bay, Hanasaki Inlet and Nemuro Harbour. Publications of the Seto Marine Biological Laboratory 1(3): 93–113.

1951. Plankton investigations in inlet waters of Japan. II. The plankton of Hakodate Harbour and Yoichi Inlet in Hokkaido. Publications of the Seto Marine Biological Laboratory 1(4): 185–194.

1952a. Plankton investigations in inlet waters of Japan. III. The plankton of Imari Bay in Kyusyu. Publications of the Seto Marine Biological Laboratory 2(2): 289–304.

1952b. Plankton investigations in inlet waters of Japan. IV. The plankton of Nagasaki Bay and Nagasaki Harbour in Kyusyu. Publications of the Seto Marine Biological Laboratory 2(2): 305–318.

1952c. Plankton investigations in inlet waters of Japan. V. The plankton of Hiroshima Bay in the Seto-Naikai (Inland Sea). Publications of the Seto Marine Biological Laboratory 2(2): 319–330.

1953a. Plankton investigations in inlet waters of Japan. VII. The plankton collected during the cruises to the new Yamato Bank in the Japan Sea. Publications of the Seto Marine Biological Laboratory 3(1): 75–108.

1953b. Plankton investigations in inlet waters of Japan. IX. The plankton of Onagawa Bay on the eastern coast of Tôhoku district. Publications of the Seto Marine Biological Laboratory 3(2): 173–187.

1953c. Plankton investigations in inlet waters of Japan. X. The plankton of Kamaisi Bay on the eastern coast of Tôhoku district. Publications of the Seto Marine Biological Laboratory 3(2): 189–204.

1954a. Plankton investigations in inlet waters of Japan. XI. The plankton of Kozima Bay in the Seto-Naikai (Inland Sea). Publications of the Seto Marine Biological Laboratory 3(3): 399–421.

1954b. Plankton investigations in inlet waters of Japan. XII. Plankton of Miyako Bay on the eastern coast of Tôhoku district. Publications of the Seto Marine Biological Laboratory 3(3): 423–441.

1954c. Plankton investigations in inlet waters of Japan. XIII. The plankton of Obama Bay on the Japan Sea coast. Publications of the Seto Marine Biological Laboratory 4(1): 103–114.

1954d. Plankton investigations in inlet waters of Japan. XIV. The plankton of Turuga Bay on the Japan Sea coast. Publications of the Seto Marine Biological Laboratory 4(1): 115–126.

1954e. Plankton investigations in inlet waters of Japan. XV. The plankton of Yosa–Naikai and Kumihama Bay, enclosed bays on the Japan Sea coast. Publications of the Seto Marine Biological Laboratory 4(1): 127–145.

1955a. Plankton investigations in inlet waters of Japan. VIII. The plankton of Miyazu Bay in relation to the water movement. Publications of the Seto Marine Biological Laboratory 4(2–3): 269–284.

1955b. Plankton investigations in inlet waters of Japan. XVI. The plankton of Tôkyô Bay in relation to the water movement. Publications of the Seto Marine Biological Laboratory 4(2–3): 285–309.

1955c. Plankton investigations in inlet waters Japan. XVII. Seasonal succession of zoopla ton in the inner area of Tanabe Bay from J to October 1954. Publications of the Seto M rine Biological Laboratory 4(2–3): 311–320.

1957. Plankton investigations in inlet waters Japan. XX. Diurnal change of plankton a mals at an innermost station in Wakaya Harbor. Publications of the Seto Marine B logical Laboratory 6(2): 209–224.

1958a. Preliminary check-list of plankton org isms found in Tanabe Bay and its enviro Publications of the Seto Marine Biological L oratory 7(1): 111–163.

1958b. A study on the productivity of the Tan Bay. Pt. I, IV. On some plankton indicat the water exchange in the Tanabe Bay. Reco of Oceanographic Works in Japan Special P lication No. 2, p. 25–35.

YAMAZI, I., and T. HORIBATA.

1955. Plankton investigations in inlet waters Japan. XVIII. Seasonal succession of plank in Taizi Bay in the years 1951–1953. Publi tions of the Seto Marine Biological Laborat 4(2–3): 321–336.

☆U.S. GOVERNMENT PRINTING OFFICE: 1961—597171

DISPLAY COP

OCEANOGRAPHY AND NORTH PACIFIC ALBACORE

JAMES W. McGARY [1]
Oceanographer
and
JOSEPH J. GRAHAM and TAMIO OTSU
Fishery Research Biologists, Honolulu Biological Laboratory [2]
U.S. Bureau of Commercial Fisheries, Honolulu, Hawaii

The purpose of this presentation is to summarize briefly the Honolulu Biological Laboratory's (HBL) oceanographic studies in the North Pacific and the oceanographic features with which are associated albacore distribution and abundance. These studies were begun in 1954 following two rather significant developments. On the negative side, the Washington and Oregon landing had fallen from a high of 34 million pounds in 1944 to less than a million pounds in 1953. On the positive side, at least scientifically, recoveries of albacore tagged with the "spaghetti" tag (Wilson 1953) had clearly demonstrated that the albacore could and did migrate from the American to the Japanese fishery (Ganssle and Clemens 1953), thus giving evidence that the oceanwide stocks are interrelated.

The HBL oceanographic and biological surveys north of Hawaii were planned to determine (1) the geographical limits and relative abundance of albacore and (2) the relationship, if any, of these to the environment, as described by oceanographic data. These studies were coordinated with those of the other research agencies through an informal Albacore Steering Committee composed of representatives of the Bureau of Commercial Fisheries and the States of Washington, Oregon, and California.

Three years were alloted for exploratory cruises to determine the distribution of albacore in the North Central Pacific, and three for the study of their abundance, migrations, and seasonal fluctuations in abundance. The latter effort was based on the premise that concentrations of commercial potential would be found. The results of a commercial charter in 1958 were disappointing, primarily because the locations of commercial concentrations of albacore are subject to large annual variations.

The major portion of both the fishing and oceanographic efforts have been to the west of 140° W. longitude. Cruises have, however, been made to the coastal areas in cooperation with other agencies and as part of our studies of the geographical and seasonal limits of albacore and their migration routes. There has been at least one complete systematic fishing survey, with limited oceanographic observations, of the area north of the Hawaiian Islands from 180° to the west coast of North America during each season of the year.

Both the oceanographic features and the summer distribution of albacore indicate that the area can be divided at about 150°-135°W. longitude, and we will follow this division in our discussion.

Figure 1 shows the extent of our oceanographic coverage to the west of 140°W. All the cruises were made in summer or winter with the exception of one made during the 1954 September-November period.

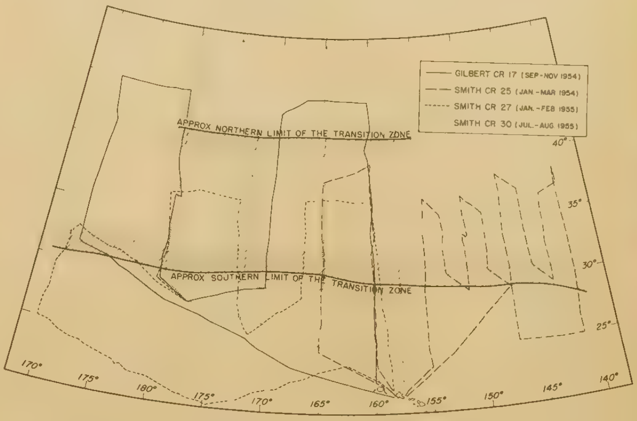

GILBERT CR 17 (SEP-NOV 1954)
SMITH CR 25 (JAN.-MAR 1954)
SMITH CR 27 (JAN.-FEB 1955)
SMITH CR 30 (JUL.-AUG 1955)
APPROX NORTHERN LIMIT OF THE TRANSITION ZONE
APPROX SOUTHERN LIMIT OF THE TRANSITION ZONE
40°
35°
30°
25°
170°
175°
180°
175°
170°
165°
160°
155°
150°
145°
140°

FIGURE 1. Tracks of four HBL oceanographic cruises to the central North Pacific.

Figure 1 is from an earlier paper (McGary et al., 1958) in which the oceanographic features were reviewed in a discussion of the possible enrichment patterns of the area. In that report the term "Transition Zone" was used to refer to the area in which the water characteristics changed from those typical of the two central North Pacific Water masses to those of the Subarctic Water mass. It was used because the authors preferred to avoid the use of the term "Polar Front", which implies a single, abrupt change. Oceanographic data showed, instead, a series of small but frequently abrupt changes. Furthermore, the large seasonal migration attributed to the Polar Front was only apparent in the surface temperature field. The zone of most abrupt change observed in winter at about 35°N. is not comparable in structure or origin to the similar zone located farther north during summer at about 43°-46°N.

---

[1] Present address: Office of Naval Research, Washington 25, D.C.

[2] Formerly known as the Pacific Oceanic Fishery Investigations (POFI).

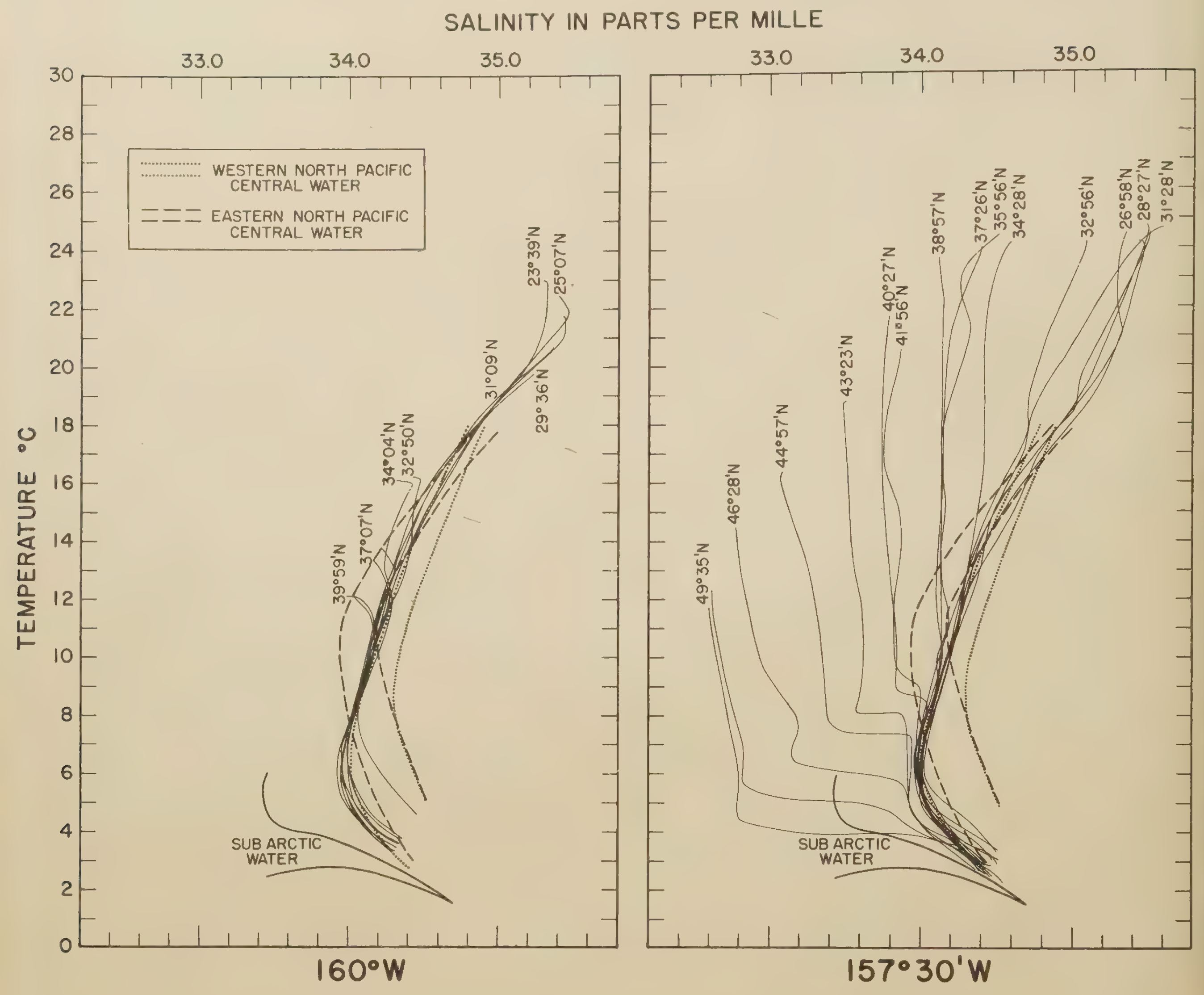


FIGURE 2. LEFT PANEL—superimposed temperature-salinity curves for the meridional station series along 160°W. longitude *Hugh M. Smith* cruise 25, January 1954. RIGHT PANEL—same along 157°W. longitude *Hugh M. Smith* cruise 30, August 1955 (McGary et al. 1958).

The temperature-salinity curves (fig. 2) from HBL winter and summer cruises, in the vicinity of 160°W., show the features used in a preliminary definition of boundaries, as well as the effect of seasonal temperature changes in the surface portion of the curves. Those from *Hugh M. Smith* cruise 25, January 1954, (McGary and Stroup 1956), show an abrupt shift in the T-S characteristics of the surface waters between 31°09′N. and 32°50′N. Shifts in the T-S curves continued northward and corresponded to areas of relatively large geostrophic currents. The position of the northern boundary cannot be defined with confidence, since this cruise did not extend far enough north to reach Subarctic Water. T-S curves from *Hugh M. Smith* cruise 30 (NORPAC) [3] (McGary et al., 1958; Hida 1957) shows two regions of abrupt shift in the surface portions of the curves. The most abrupt shift occurred between 32°56′N. and 34°28′N. Farther to the north another such shift occurred between 41°56′N. and 43°23′N. North of that latitude, the shifts were large but were uniform latitudinally. At 43°23′N. and northward, a salinity minimum was present at the surface, which is in keeping with the definition of Subarctic Water (Sverdrup et al., 1942, p. 722).

The salinity cross sections were examined and boundaries roughly set by the following criteria (see fig. 3). The southern boundary was set as the northern limit of the area within which the warming during all seasons was sufficient to maintain a lens of high salinity water at the surface. The northern boundary was taken as the southern extreme of the area in which the lens of low salinity water, from precipitation or other sources, was sufficient to withstand the effects of winter cooling or was not mixed

---

[3] NORPAC was the code name given to a quasi-synoptic oceanographic survey of the North Pacific during the summer of 1955 by research agencies of Canada, Japan, and the United States.

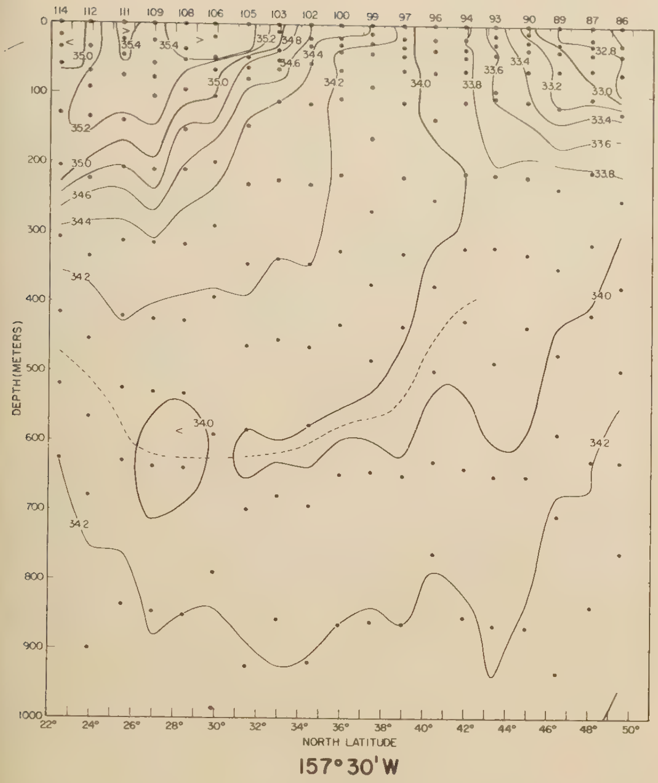


FIGURE 3. Salinity cross section 157°30′W., *Hugh M. Smith* cruise 30, August 1955.

sufficiently with more saline water to the south to cause it to sink even during winter. The limits of the Transition Zone shown in figure 1 were drawn on this basis. The differences in the sections for the various seasons showed, as expected, that the southern limit was 1°-2° of latitude farther south in winter than in summer. Only summer data were available to the north but no doubt the northern limit shifts to the north in winter, since cooling would break up the shallow southern limit of the lens.

Comparison of the longitudinal sections from *Hugh M. Smith* cruise 25 (January-March 1954) showed that boundaries and sharp changes in the T-S curves became less distinct from west to east (Stroup and McGary, 1956).

Reports by Japanese oceanographers suggest that the Transition Zone extends westward to the area immediately off Japan and that it narrows to the west. Uda (1943) described a double frontal system in the Kuroshio, and Masuzawa (1957) discussed the structure in more detail. The latter reported the width of the "Frontal Zone" between the warm and cold water to be 200-300 miles within about 500 miles of the coast. In general, he stated that the "Polar Frontal Zone" shows particularly predominant discontinuities along both the northern and southern edges. He also found that the northern edge was not as well defined as the southern edge.

The surface and vertical temperature distributions typical of the Transition Zone are shown in figure 4. The contrast between the summer and winter profiles shows the effect of seasonal heating and cooling. During both cruises the subsurface isotherms rose abruptly, e.g. 60°F., in the vicinity of the southern limit of the Transition Zone. In winter, the northern limit of this ascent marked the beginning of the zone with little or no distinct surface layer; in summer, it marked the beginning of a very shallow surface layer with an extremely sharp thermocline. At the northern limit of the Transition Zone, the 50°F. isotherm marked the boundary of a distinct difference in the subsurface structure; to the north it marked the beginning of an area with frequent small inversions below the thermocline. The surface temperatures of both seasons showed a striking coincidence in the temperature range at which the greatest horizontal gradient occurred: on both sections inspection showed it was between 56° and 68°F. with the maximum usually occurring between 58° and 62°F. Inspection of other transects shows that this is true of all seasons of the year, both in the central and eastern Pacific (Shomura and Otsu, 1956; Graham, 1957). In spring, the zone of surface temperature discontinuity is associated with the development of the shallow thermocline and its northward advance as summer approaches. It also coincides with the southerly movement of the breakup of the shallow warm surface layer in fall and winter.

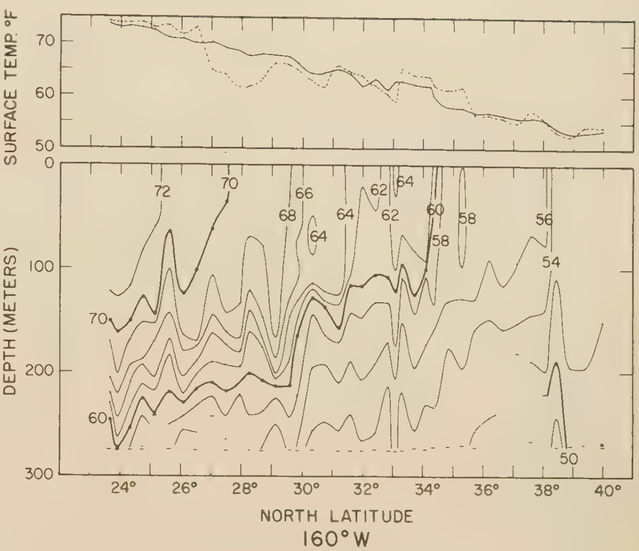


FIGURE 4a. Temperature section from BT casts along 160°W., *Hugh M. Smith* 25, January 1954. Broken line in upper panel shows surface air temperature.

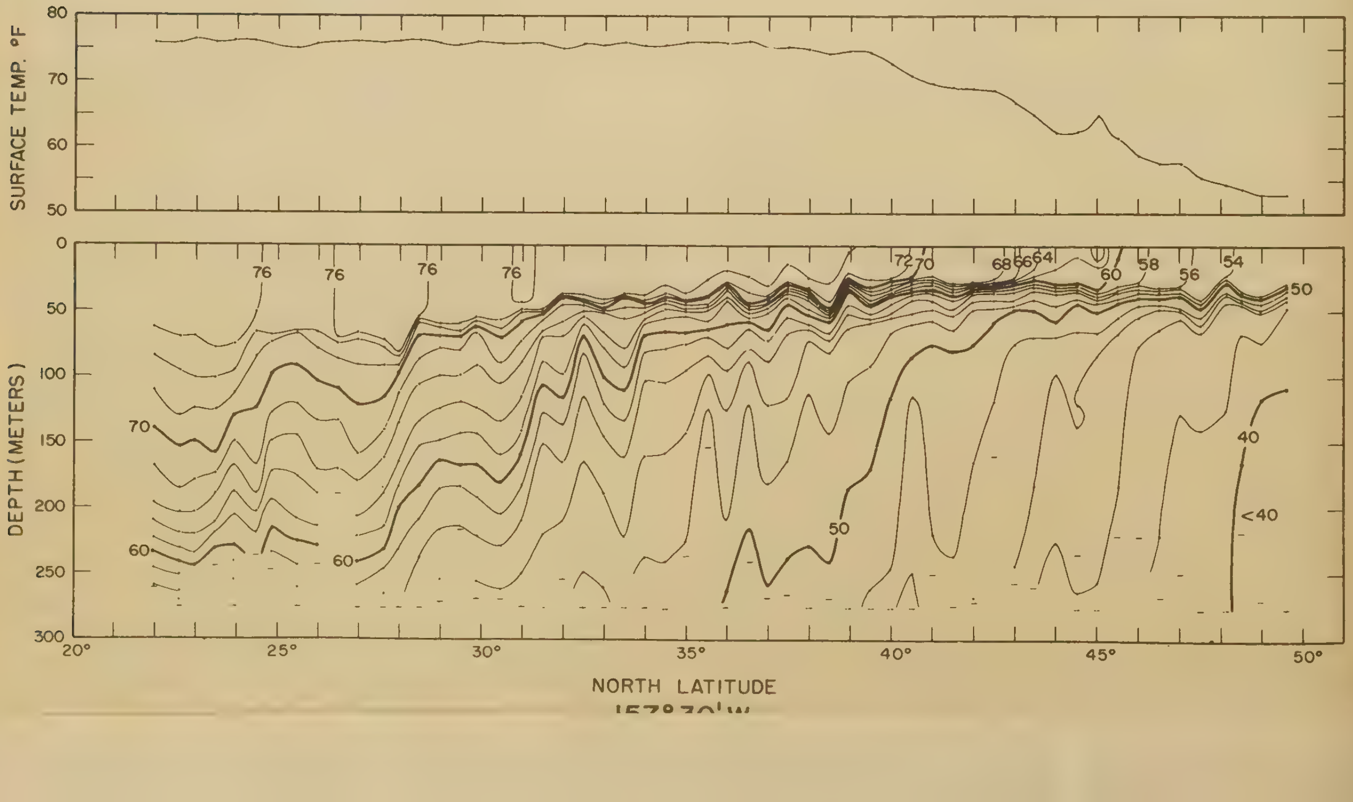
Hida (1957), in a study of the distribution of chaetognaths and pteropods in the North Pacific, found that these oceanographic divisions coincided with faunal divisions and, in fact, the term "Transition Zone" in the sense used here was introduced in his report. Jones (McGary et al., 1958), in a study of copepods, found that the formation of the warm surface layer apparently offered favorable conditions for phytoplankton blooms, followed by an increase in zooplankton standing crop. However, the latter was not characterized by a meridional advance of tropical species, but rather by the development of "blooms" of eurythermal forms such as *Calanus helgolandicus* and *C. tonsus.*

It cannot be ascertained from the data at hand whether (1) the distribution of albacore is controlled directly by surface temperature (presumably through physiological mechanisms) or whether (2) the distribution of albacore is related only indirectly to surface temperature through the seasonal march of events leading to a large standing crop of forage organisms. In rebuttal to the hypothesis of direct relationship, data from other areas do not always show the same albacore-temperature relationship, and within the survey area uniform distribution with temperature did not occur from area to area or season to season. In rebuttal to the forage hypothesis, the seasonal movement of the biological frontier coincided with the movement of the isotherms, but it did not indicate the presence of albacore in all seasons nor in all parts of the survey area.

In figure 5, the total catch of albacore is shown as the percentage of the catch made at different surface temperatures. The total catch includes all of the albacore taken by HBL in the central Pacific by troll and gill net during all seasons. For comparative purposes, similar examples from the east and west have been included. The curve shows that the central Pacific catches were made within a narrow temperature band, with a dominant mode between 58° and 60°F. The overall range may be narrowed to about 55°F-66°F., since almost all of the catches at temperatures below 55°F. were made in the fall immediately after periods having winds of Force 6 or greater and it was evident that the area had experienced a recent sharp temperature decline because of wind-induced overturn (Shomura and Otsu 1956, Graham MS[4]). The *Cobb* data are typical of the fishery which frequently develops off the coast of British Columbia, Washington, and Oregon during the late summer (Powell and Hildebrand, 1950) and indicate that the albacore occur in the same narrow temperature range as in the central Pacific. The *Jini Maru* plot was constructed from data collected in the spring live-bait fishery off Japan during a cooperative tagging program conducted in the spring of 1956 by the Japanese Fishery Agency and HEL (Van Campen and Murphy, 1957). These data are representative of this fishery. Here, the temperature range and mode are even more sharply defined than in the other two plots. These conditions

---

[4] J. J. Graham, "Macroecology of the albacore, **Thunnus germo** (Lacepede), in the central North Pacific" MS.



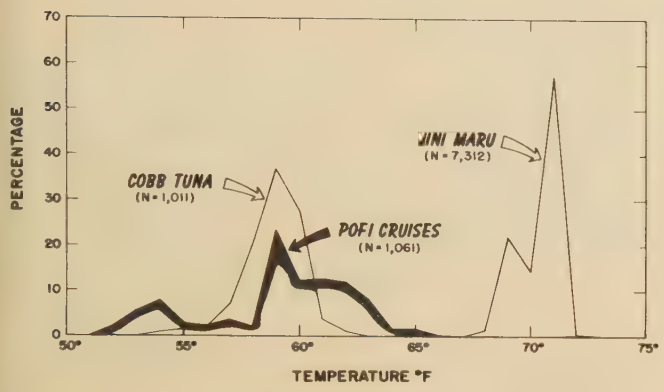


FIGURE 5. Percentage of albacore catch versus temperature of catch.

arise in part from the fact that the *Jini Maru* was engaged in commercial fishing and an effort was made to stay with the maximum concentration of fish. However, in spite of the fact that the general oceanographic features of the area indicate that the *Jini Maru* data were taken in the western extremity of the Transition Zone, the temperature range does not even overlap that of the central and eastern Pacific.

A discussion of the seasonal distribution of albacore will serve to illustrate the use and limitation of temperature as an indicator of the areas in which albacore might be expected to occur. Beginning with winter, a comparison of the catches of *John R. Manning* cruise 19 along 160°W. (fig. 6) during January 1954 with the temperature profile from *Hugh M. Smith* cruise 25 (see also fig. 4a) shows that the deep swimming albacore captured on longline gear occurred in an area having surface temperatures of 56°-66°F. and just south of the point where the largest horizontal temperature gradients occurred.

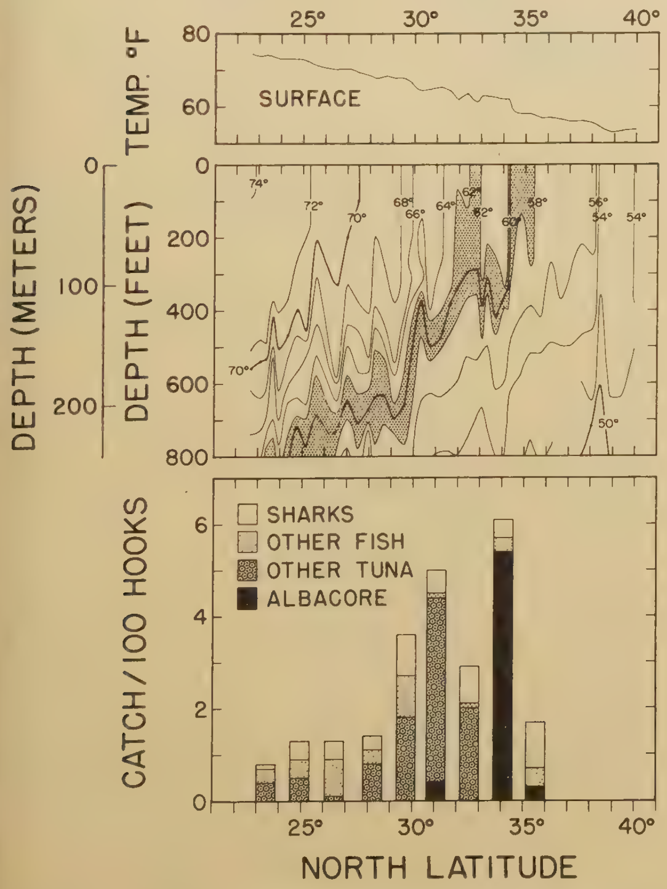


FIGURE 6. Vertical temperature profile, *Hugh M. Smith* cruise 25, January 1954 and longline catch/100 hooks, *John R. Manning* cruise 19, January 1954, along 160°W. longitude.

Figure 7 shows the winter distribution of albacore in the eastern North Pacific as indicated by the surveys of 1955 and 1956 and the Japanese winter fishery. It shows quite clearly that the latitudinal limits are almost coincident with the southern boundary of the Transition Zone (fig. 1) and the temperature front (fig. 4 and 6) and are not associated with the subtropical convergence as originally hypothesized. The dynamic topographies from the 1954 and 1955 winter cruises indicate that the subtropical convergence was in the vicinity of 24°-27°N. during both years (McGary and Stroup, 1956 and 1958). Suda (1958) also described the subtropical convergence as an area of minimal albacore catch in the western Pacific.

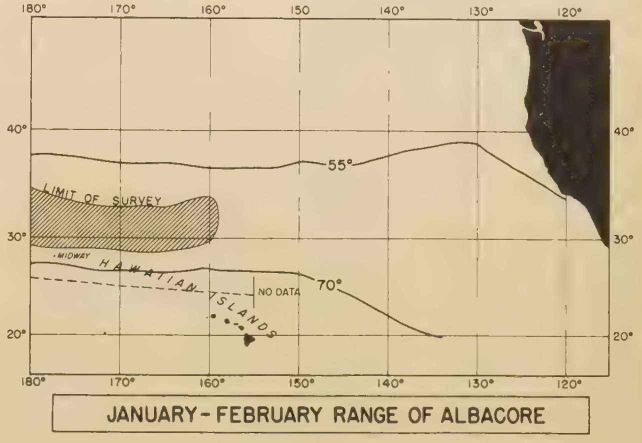


FIGURE 7. Winter distribution of albacore in the eastern North Pacific. Dashed lines indicate position of Subtropical Convergence from *Hugh M. Smith* cruises 25 (January-March 1954) and 27 (January-February 1955).

Our spring cruises (1955 and 1956) showed a conspicuous band of phytoplankton and zooplankton abundance in the 55°65°F. surface temperature range between 180° and 140°W. There was an abundance of forage organisms and a rich phytoplankton bloom was indicated by the Forel color of the water, but few albacore were caught. Only one was taken east of 170°W., and only a few scattered fish to the west of 170°W. on all three types of gear (troll, longline, and gill net).

During the fall of 1954, 1955, and 1956 albacore were taken in considerable quantities from offshore of San Francisco to 170°E. longitude, the western limit of the survey area. They were taken in waters with surface temperatures between 55°F. and 65°F., with the peak catches ocurring in the 58°-60°F. range.

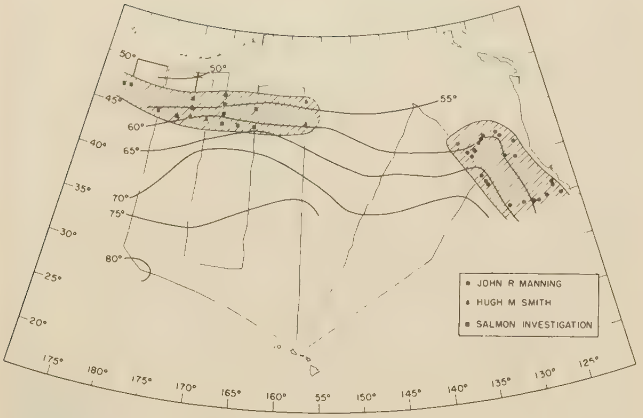


FIGURE 8. Location of albacore taken in the North Pacific by exploratory vessels, July-September 1955.

Again, this temperature appeared to coincide quite well with the biological frontier.

During the summer of 1955, because of NORPAC and the activity of the North Pacific Salmon Investigations, there was excellent coverage between 175°E. and the west coast of North America. The results showed two interesting features. Firstly, the albacore were divided into two groups, one in mid-ocean extending as far east as 155°W. (fig. 8) and the other extending northwest from the California fishery. The existence of the area of albacore scarcity has been at least partially verified in all subsequent summer surveys. Secondly, comparison of figure 4 and figure 8 shows that the mid-ocean albacore were in a shallow surface layer in Subarctic Water (figure 2) and at about the same surface temperature range as during the other seasons. The *J. R. Manning* returned to the area in 1956 and found a similar situation (fig. 9) with an even more pronounced biological frontier indicated by the plankton abundance and light penetration readings. In 1958 the 1955 and 1956 summer surveys were followed up by a commercially unsuccessful gill net effort from the chartered vessel *Paragon*. Again the fish were found in the warm layer in the southern limits of Subarctic Water, but the center was 3°-4° farther south, and the standing crops of plankton and forage were much less than observed at corresponding temperatures for the previous years.

The hydroptic charts for the mid-August period for the past four years illustrate the amount the temperature field can shift in mid-ocean and the radical changes in local temperature that result. The lower panel, figure 10, shows the variation in location of the 55° to 66°F. surface temperature band that approximates the limits of albacore distribution. As a result of such variations, annual differences of up to 10°-12°F. can occur at a given locality. This could make considerable difference in the development of the seasonal plankton cycle in the area, particularly when one considers that the average seasonal range in temperature is only 15°F. The upper panel shows the latitudinal changes in the temperature range that corresponds to the peak of the albacore abundance in the central and northeastern Pacific. It illustrates the small amount of latitudinal change necessary to produce the 10°-12°F. temperature anomalies.

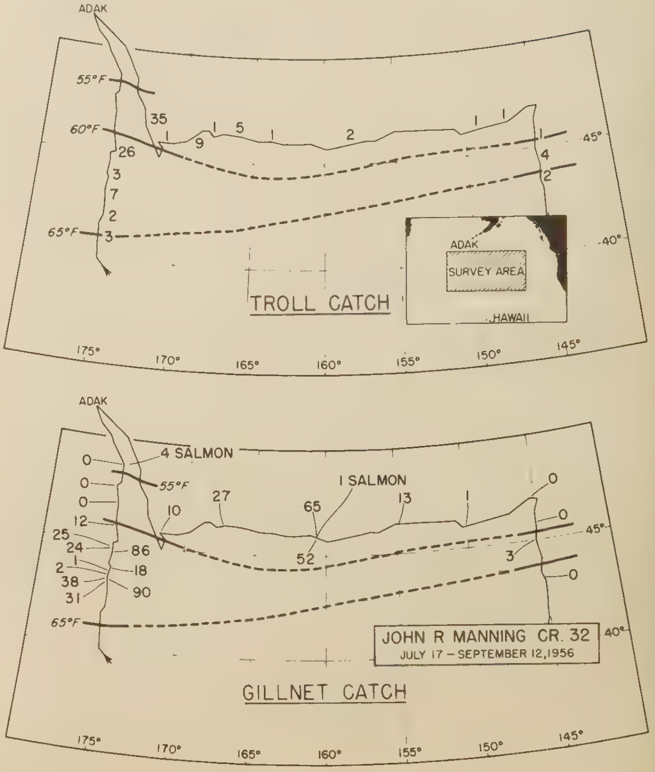
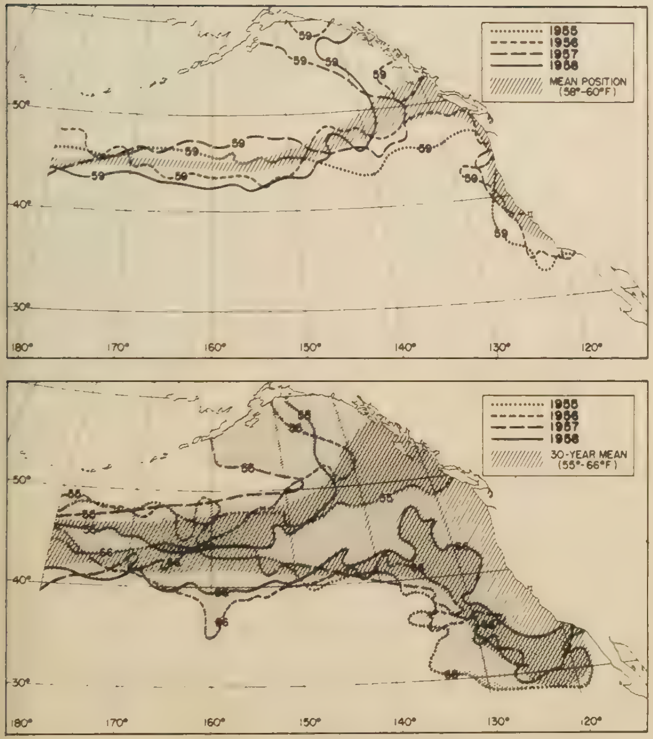


FIGURE 9. Summer 1956 albacore survey, *John R. Manning* cruise 32.

The existence of a "tongue" of albacore extending northwest from the California fishery in 1955 (fig. 8) and the work of Powell and Hildebrand (1950), Powell et al. (1952), Shaefers (1951), and Partlo (1950) suggest conditions under which the Pacific Northwest fishery develops. First, albacore may be present in the summer off the northwest coast during all years but move into and concentrate in the coastal waters of British Columbia, Oregon, and Washington only when oceanographic conditions (exact nature unspecified) are favorable. Second, the extent in time and space of the coastal band of upswelling may also influence the development of the fishery and limit its shoreward extent.

During the last 10 days of July 1957, nine chartered commercial trollers and two HBL vessels made a synoptic survey of the distribution and abundance of the albacore in the coastal area between 35°N. and 47°N. The results of the survey (fig. 11) showed that these fish were present in a wide band along the coast. In the northern part of the survey area, albacore were most abundant offshore of the area of largest surface temperature gradient which indicated the outer limit of the band of upwelling (fig. 12). However, their distribution was far from continuous and was not completely associated with any feature of the boundary, such as the tongues of relatively warm water which penetrated shoreward.

The radical annual temperature differences shown


1955
1956
1957
1958
MEAN POSITION (58°-60°F)
30-YEAR MEAN (55°-66°F)
59
55
66
50°
40°
30°
180°
170°
160°
150°
140°
130°
120°

AUGUST 11-20 SURFACE ISOTHERMS

FIGURE 10. LOWER PANEL—mid-August mean and 1955 through 1958 positions of the 55° and 66°F. isotherms; UPPER PANEL—mid-August mean and center of the 58°-60°F. isotherms for 1955 through 1958.

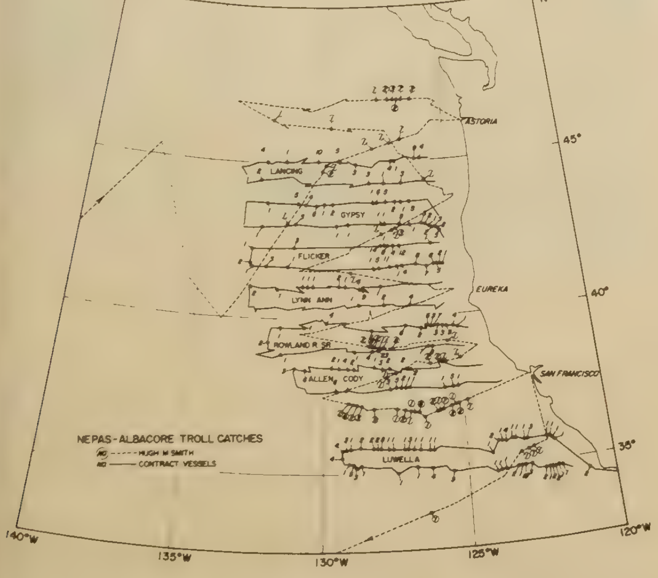

50° N
45°
40°
35°
ASTORIA
EUREKA
SAN FRANCISCO
LANCING
GYPSY
FLICKER
LYNN ANN
ROWLAND R.
ALLEN, CODY
LUWELLA
NEPAS-ALBACORE TROLL CATCHES
HUGH M SMITH
CONTRACT VESSELS
140°W
135°W
130°W
125°W
120°W

FIGURE 11. NEPAS (Northeastern Pacific Albacore Survey) troll catches, July 1957.

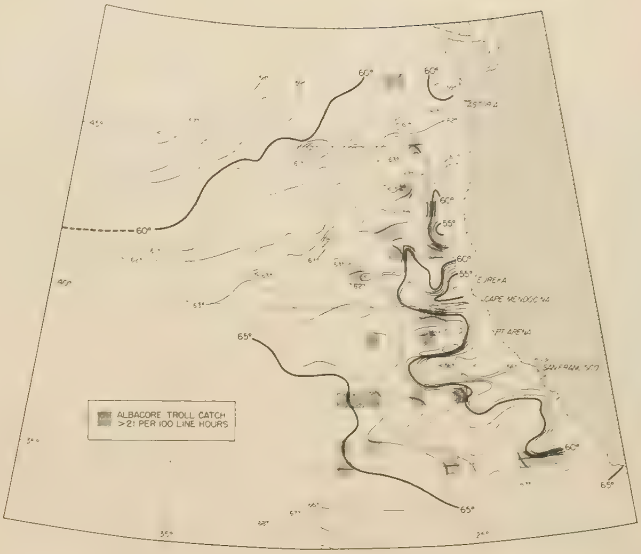
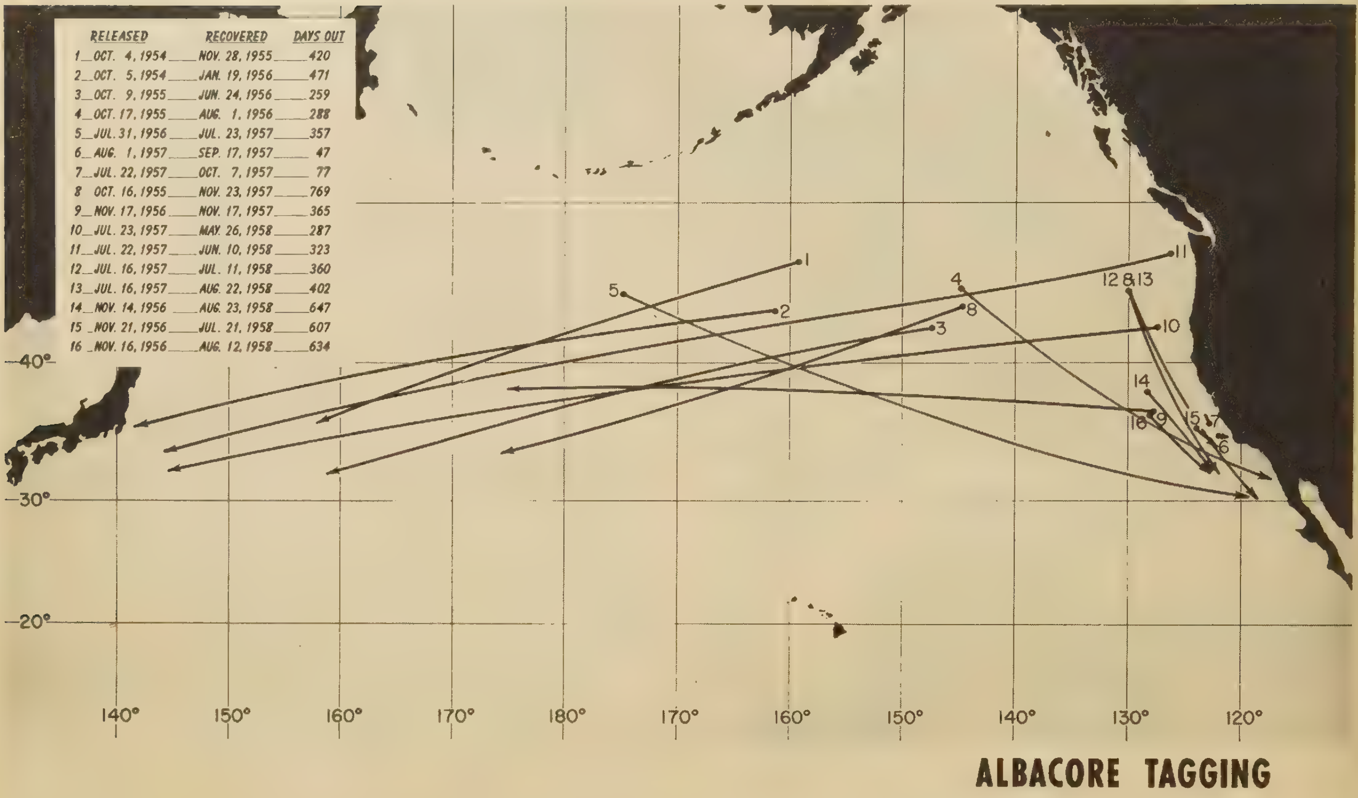

60°
55°
65°
EUREKA
CAPE MENDOCINO
PT ARENA
SAN FRANCISCO
ALBACORE TROLL CATCH >21 PER 100 LINE HOURS

FIGURE 12. NEPAS surface temperatures and best albacore catch rates.

also account in part for the yearly fluctuations in the landings of the California fishery as well as the radical fluctuations in the Pacific Northwest fishery. The charts show that suitable temperature conditions for albacore may in some years occur as far north as Kodiak Island and lend credence to reports of albacore in the Gulf of Alaska in 1957 and 1958.

Not all of our efforts have been confined to exploratory fishing work. Results from our tagging experiment, literature research, and age, growth, and spawning studies have given us a reasonably plausible picture of albacore migration routes in relation to oceanographic features. One thousand two hundred and six albacore have been tagged. In addition, we have helped establish a tagging experiment in the Japanese live-bait fishery. Figure 13 shows the points of release and recapture of our 16 returns. It shows migration from the mid-ocean area to both the American and the Japanese fisheries and movement from the American to the Japanese fishery. Recoveries from California Fish and Game tag releases (Ganssle and Clemens 1953) also show this latter movement. Japanese tag returns (K. Mimura, personal communication) have shown rapid easterly movements within their spring live-bait fishery. On the basis of these returns, the oceanography, our spawning and growth studies (Otsu and Uchida, 1959a and b), and Suda's (1958) paper on migration within the Japanese fishery, we have arrived at the somewhat incomplete pattern of albacore migrations shown in figure 14. Here we show an easterly spring and summer migration along the 55°-65°F. temperature frontier in the Transition Zone and a westward migration along it in the fall and winter. The lack of an apparent connective link between the two segments of the eastern migration may be because the Japanese tagging experiment has only begun recently. Also, their tagging has been primarily in their live-bait fishery, which, in general, takes larger fish than the American west coast fishery. The postulated spawning area is located



RELEASED	RECOVERED	DAYS OUT
1 OCT. 4, 1954	NOV. 28, 1955	420
2 OCT. 5, 1954	JAN. 19, 1956	471
3 OCT. 9, 1955	JUN. 24, 1956	259
4 OCT. 17, 1955	AUG. 1, 1956	288
5 JUL. 31, 1956	JUL. 23, 1957	357
6 AUG. 1, 1957	SEP. 17, 1957	47
7 JUL. 22, 1957	OCT. 7, 1957	77
8 OCT. 16, 1955	NOV. 23, 1957	769
9 NOV. 17, 1956	NOV. 17, 1957	365
10 JUL. 23, 1957	MAY. 26, 1958	287
11 JUL. 22, 1957	JUN. 10, 1958	323
12 JUL. 16, 1957	JUL. 11, 1958	360
13 JUL. 16, 1957	AUG. 22, 1958	402
14 NOV. 14, 1956	AUG. 23, 1958	647
15 NOV. 21, 1956	JUL. 21, 1958	607
16 NOV. 16, 1956	AUG. 12, 1958	634

FIGURE 13. Chart of points of release and return of tagged albacore.

in the North Equatorial Current and is based on studies of albacore landed in the Hawaiian longline fishery as well as on HBL's exploratory cruises and data from the Japanese longline fishery in the west.

REFERENCES

Ganssle, D., and H. B. Clemens, 1953. California-tagged albacore recovered off Japan. *California Fish and Game* **39**(4): 443.

Graham, J. J., 1957. Central North Pacific albacore surveys, May to November 1955. *U.S. Fish and Wildlife Service, Special Scientific Report—Fisheries No. 212*, 38 p.

Hida, T. S., 1957. The chaetognaths and pteropods as biological indicators in the North Pacific. *U.S. Fish and Wldlife Service, Special Scientific Report—Fisheries No. 215*, 13 p.

Masuzawa, J., 1957. A contribution to the knowledge of the Kuroshio east of Japan. *The Oceanographic Magazine* **9**(1): 21-34.

McGary, J. W., and E. D. Stroup, 1956. Mid-Pacific oceanography, Part VIII, middle latitude waters, January-March 1954, *U.S. Fish and Wildlife Service, Special Scientific Report—Fisheries No. 180*, 173 p.

1958. Oceanographic observations in the central North Pacific, September 1956-August 1955, *U.S. Fish and Wildlife Service, Special Scientific Report—Fisheries No. 252*, 250 p.

McGary, J. W., E. C. Jones, and J. J. Graham, 1958. Enrichment in the Transition Zone between the Subarctic and Central Water masses of the central North Pacific. *Proceedings of the 9th Pacific Science Congress, 1957*, **16**: 82-89..

Otsu, T., and R. N. Uchida, 1959a. Sexual maturity and spawning of albacore in the Pacific Ocean, *U.S. Fish and Wildlife Service, Fishery Bulletin 59* (148): 287-305.

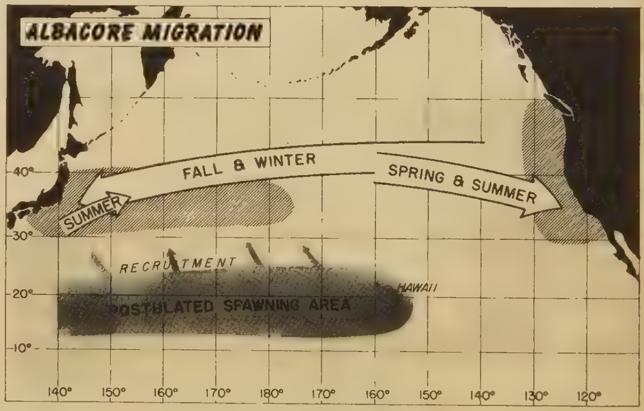


FIGURE 14. Albacore migration.

1959b. Study of age determination by hard parts of albacore from central North Pacific and Hawaiian waters, *U.S. Fish and Wildlife Service, Fishery Bulletin 59* (150): 353-363.

Partlo, J. M., 1950. A report on the 1949 albacore fishery *(Thunnus alalunga). Fisheries research Board of Canada, Circular No. 20.*

Powell, D. E., and H. A. Hildebrand, 1950. Albacore tuna exploration in Alaskan and adjacent waters, 1949. *U.S. Fish and Wildlife Service, Fishery Leaflet 376*, May.

Powell, D. E., D. L. Alversen, and R. Livingstone, Jr., 1952. North Pacific albacore tuna exploration, 1950. *U.S. Fish and Wildlife Service*

Shaefers, E. A., 1953. North Pacific albacore tuna exploration, 1952, *U.S. Fish and Wildlife Service, Commercial Fisheries Review* 15(9) : 1-6.

Shomura, R. S., and T. Otsu, 1956. Central North Pacific albacore surveys, January 1954-February 1955, *U.S. Fish and Wildlife Service, Special Scientific Report—Fisheries No. 173*, 30.

Suda, A., 1958. Recruitment and dispersion of the North Pacific albacore. *Report of Nankai Regional Fisheries Research Laboratory, No. 9.* (Translation by G. Y. Beard)

Sverdrup, H. W., M. W. Johnson, and R. H. Fleming, 1942. "The Oceans, their Physics, Chemistry, and General Biology." Prentice Hall, Inc., 1087.

Uda, M., 1943. On the structure of the boundary zone of different water masses. *Journal of the Oceanographic Society of Japan* 2(4).

Van Campen, W. G., and G. I. Murphy, 1957. Tagging albacore on a Japanese bait boat. *Pacific Fisherman* 55(3) : 37, 39, 41-43.

Wilson, R. C., 1953. Tuna marking, a progress report. *California Fish and Game* 37(4).

UNDERWATER OBSERVATION CHAMBERS ON THE RESEARCH VESSEL "CHARLES H. GILBERT"

By

HERBERT J. MANN

INTRODUCTION

This report is a description of the special experimental stern and bow observation chambers which have been installed on the research vessel Charles H. Gilbert, of the U. S. Bureau of Commercial Fisheries Biological Laboratory, Honolulu, for the purpose of studying tuna behavior at sea. A general account of these facilities, including comments on their effectiveness in observing fish underwater, has already been published (Strasburg and Yuen, 1960). This supplementary report is for the purpose of describing such construction details of the Charles H. Gilbert's chambers as may be of interest to naval architects or others planning similar installations.

The Charles H. Gilbert (fig. 1) is a single-screw, long-range steel trawler especially designed for oceanographic and fishery research work in the central Pacific. Since her launching in 1952, the vessel has undergone a number of alterations to meet the needs of various research programs. The stern and bow chambers shown in the profile view were not part of the original vessel, but were added in 1959 and 1960 to fill the needs of a tuna behavior study program.

This program is concerned, in part, with a study of skipjack behavior as related to the live-bait fishing methods. Such fishing is carried out from the Charles H. Gilbert in a manner similar to that used on Hawaiian sampans. Fish are tracked by following the bird flocks which accompany surface schools, diverted to the stern by chumming with live bait, and are hooked with pole and line from racks arranged around the stern and the port side of the vessel (fig. 1, plan view). Fishing activity normally centers around the quarter rack, rather than at the stern or farther forward.

Required by the behavior studies was a means of positioning an observer below the surface in a location close to this center of fishing activity and under conditions in which the response of fish to lures and bait could be recorded and photographed. An additional requirement was that observation should be possible at all vessel speeds, from the maximum when chasing schools, to the minimum when hooking fish.

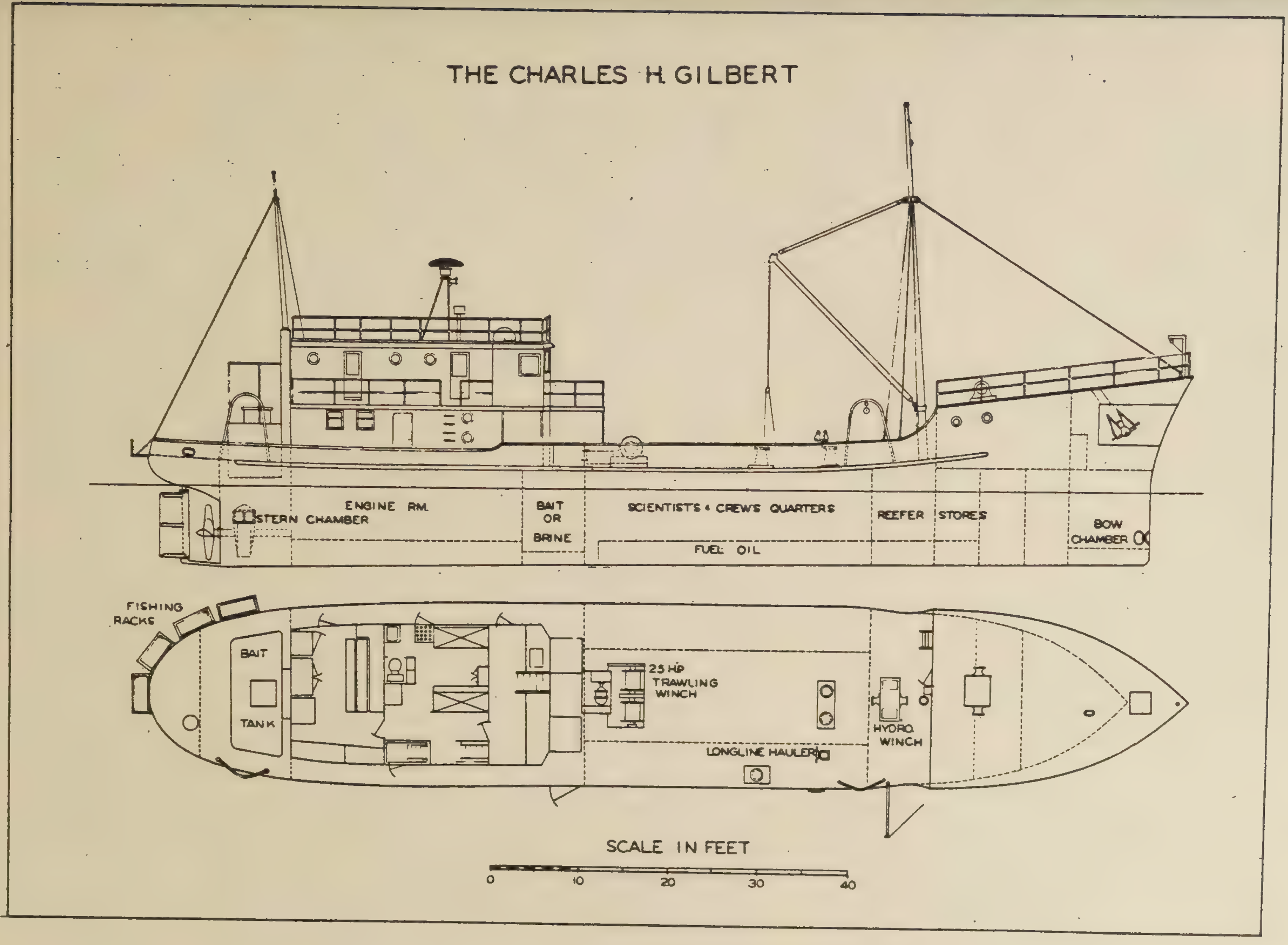

THE CHARLES H. GILBERT
ENGINE RM.
STERN CHAMBER
BAIT
OR
BRINE
SCIENTISTS & CREWS QUARTERS
FUEL OIL
REEFER
STORES
BOW
CHAMBER
FISHING
RACKS
BAIT
TANK
25 HP
TRAWLING
WINCH
LONGLINE HAULER
HYDRO.
WINCH
SCALE IN FEET
0
10
20
30
40

Fig. 1.--Profile and plan view of the Charles H. Gilbert.

A number of experimental installations were used to test the feasibility of observing fishing activity under water from a vessel under way. Such tests included an overside ladder and perch for a diver and an elaborate, retractable caisson in which an observer could be carried several feet below the surface. These temporary installations showed a stern chamber to be practicable, provided problems of turbulence could be overcome.

THE STERN CHAMBER

Using information gained from preliminary studies, a permanent stern chamber was designed and installed on the Charles H. Gilbert in 1959. The general appearance of the chamber, especially as related to body lines of the hull, is shown in fig. 2. Its precise location was arrived at by balancing out several design factors: minimum disturbance to the hull streamlines, maximum depth of observer's eye beneath the surface, proximity to the area of greatest fishing activity, and utilization of the stern fuel tank for access. The final plan adopted was for the port-side hull blister shown, with accommodation for an observer standing upright in a semi-cylindrical streamlined shell. Twin ports provided a wide angle of view from astern of the vessel to well past abeam.

Details of the blister construction are shown in figs. 2 and 3. A half-cylinder, 22 in. in diameter, of rolled 1/4 in. plate was welded around an opening through the stern fuel tank shell plating. Gussets of 1/4 in. plate between the cylinder and hull provided additional stiffening. Fairing was accomplished by welding a framework of 1/2 in. reinforcing rods between gussets; expanded metal was laid over this skelton framework and the whole was covered with quick-drying concrete and smoothed to a streamlined shape (fig. 3). Thin edges of concrete fairing next to the hull were protected by a 3/8 x 2 in. flat bar grounding strip welded all around the chamber at an angle to the shell plating.

Details of the methods of installing glass viewing ports are shown in fig. 4. Special precautions were used to protect the ports from shock due to vibration of the propeller shaft and "panting" of the hull. Square panes of polished tempered plate glass, 1 x 14 x 14 in., cushioned by 1/16 in. thick neoprene gaskets inside and out were shock mounted between heavy "L" shaped frames carefully machined to a close fit. Frames were drawn together by 1/2 in. diameter stainless steel studs at 1-7/8 in. intervals. All components were of stainless steel to avoid pressure on the panes from corrosion.

Access to the chamber is through the stern fuel tanks by means of a narrow, covered hatch opening on the main deck. Communication with the bridge is maintained by a sound-powered headphone (Bureau of Ships, Type SA-7B). Ventilation is accomplished by a forced-draft blower system operating through 10 in. ducts.

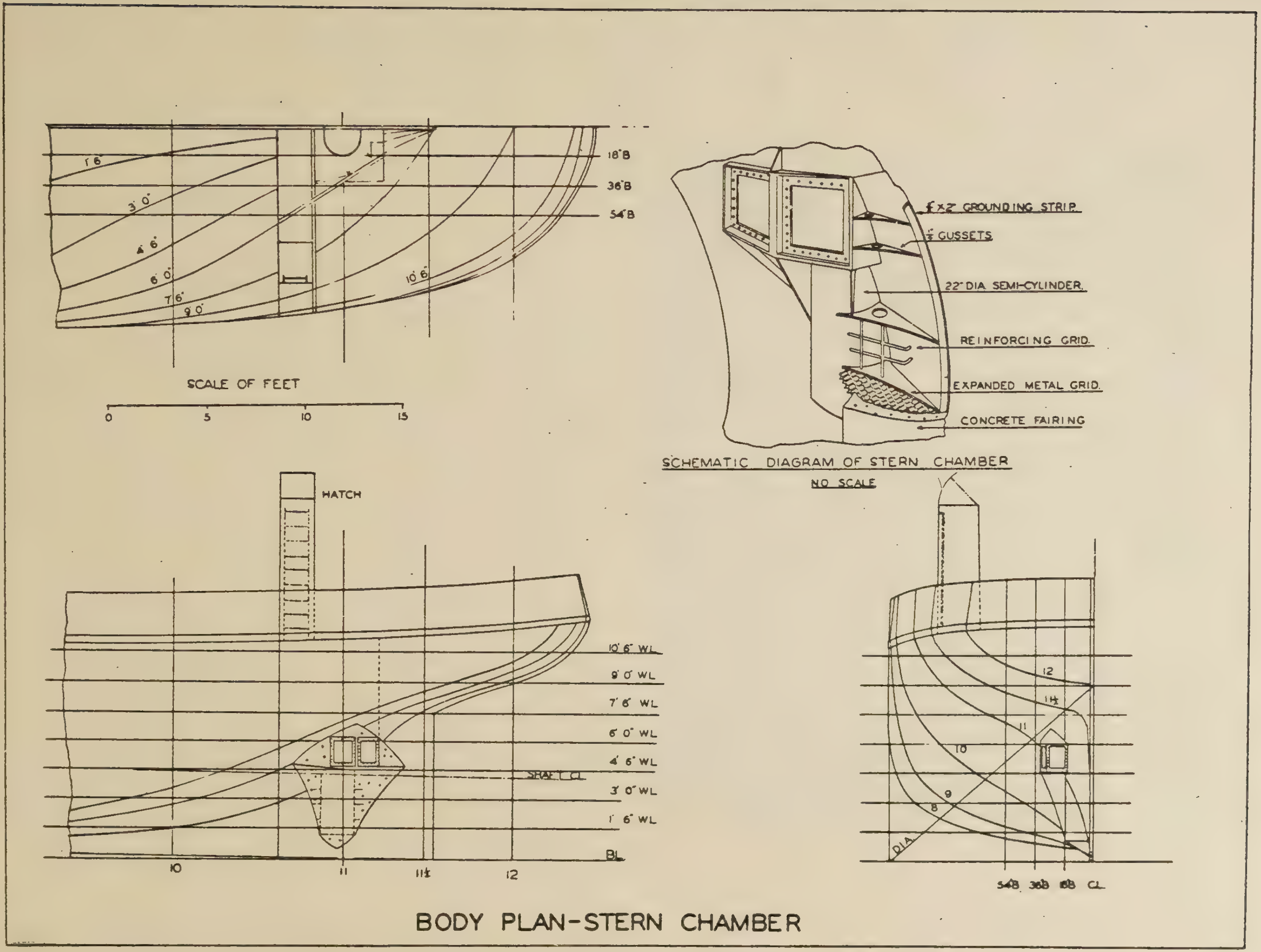

1'6"
3'0"
4'6"
6'0"
7'6"
9'0"
10'6"
18"B
36"B
54"B
SCALE OF FEET
0
5
10
15
½ x 2" GROUNDING STRIP
¼" GUSSETS
22" DIA SEMI-CYLINDER
REINFORCING GRID
EXPANDED METAL GRID
CONCRETE FAIRING
SCHEMATIC DIAGRAM OF STERN CHAMBER
NO SCALE
HATCH
10'6" WL
9'0" WL
7'6" WL
6'0" WL
4'6" WL
3'0" WL
1'6" WL
BL
SHAFT CL
10
11
11½
12
8
9
10
11
11½
12
DIA
54B
36B
18B
CL
BODY PLAN-STERN CHAMBER

Fig. 2.--The *Charles H. Gilbert*'s stern chamber.

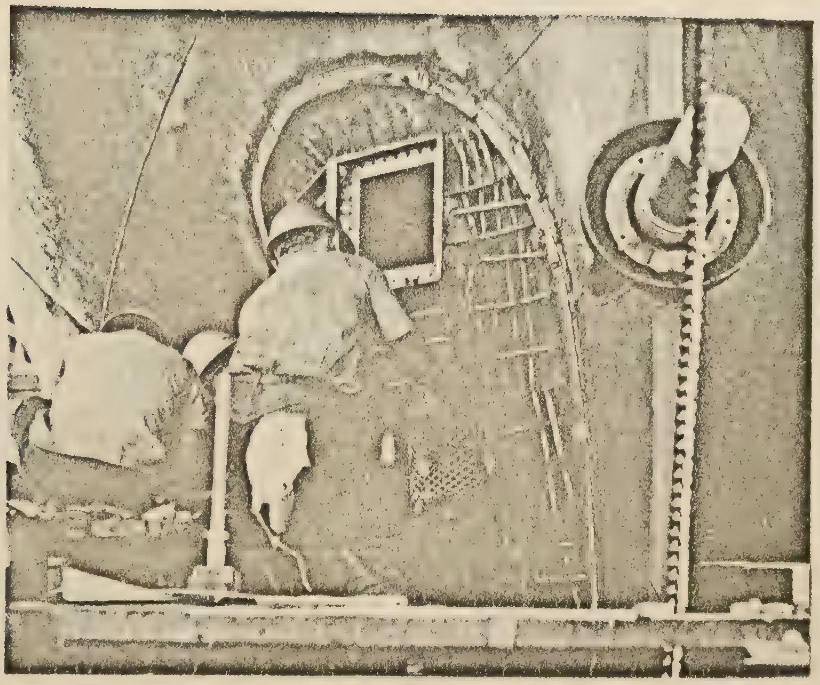


Fig. 3.--The Charles H. Gilbert's stern chamber during construction. Expanded metal framework being welded in place preparatory to concrete plastering.

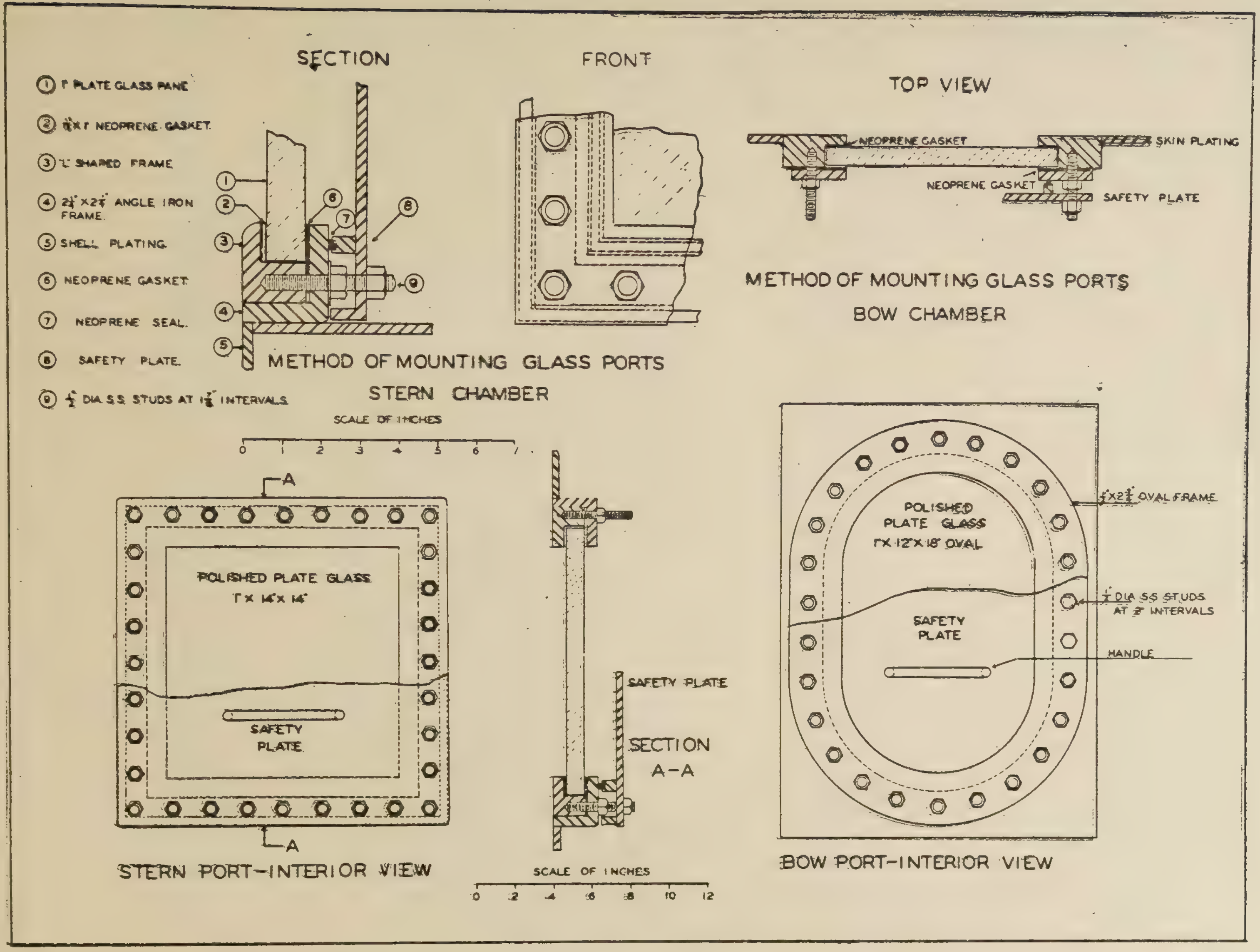

SECTION
FRONT
TOP VIEW
① 1" PLATE GLASS PANE
② 1/8"x1" NEOPRENE GASKET.
③ "L" SHAPED FRAME
④ 2 1/4"x2 1/4" ANGLE IRON FRAME.
⑤ SHELL PLATING.
⑥ NEOPRENE GASKET.
⑦ NEOPRENE SEAL.
⑧ SAFETY PLATE.
⑨ 1/2" DIA S.S. STUDS AT 1 7/8" INTERVALS.
①
②
③
④
⑤
⑥
⑦
⑧
⑨
METHOD OF MOUNTING GLASS PORTS
STERN CHAMBER
SCALE OF INCHES
0 1 2 3 4 5 6 7
NEOPRENE GASKET
SKIN PLATING
NEOPRENE GASKET
SAFETY PLATE
METHOD OF MOUNTING GLASS PORTS
BOW CHAMBER
A
POLISHED PLATE GLASS
1" x 14" x 14"
SAFETY
PLATE
A
STERN PORT-INTERIOR VIEW
SAFETY PLATE
SECTION
A-A
SCALE OF INCHES
0 2 4 6 8 10 12
POLISHED
PLATE GLASS
1" x 12" x 18" OVAL
1/2"x2 1/2" OVAL FRAME
1/2" DIA S.S. STUDS
AT 2" INTERVALS
SAFETY
PLATE
HANDLE
BOW PORT-INTERIOR VIEW

Fig. 4.—Construction details of stern and bow chamber ports.

To maintain watertight integrity, ports when not in use may be covered by 1/4 in. thick cover plates. The studs used for mounting glass panes are also used for securing the plates, and neoprene seals seated against the port frames make the plates oil- and watertight.

THE BOW CHAMBER

A bow chamber for tracking outlying schools of fish was a logical outcome of an effective stern chamber. However, since the vessel's existing bow had too much rake to accommodate a chamber, the whole forward section was cut away and a new bulbous bow of the design shown substituted (figs. 5 and 6). The "bulb" houses an ideally shaped bow chamber which projects forward of the vessel's turbulence. Three ports afford a wide-angle view well below the waterline. The chamber is backed by a collision bulkhead for protection in case of damage to the ports. Access is through a watertight hatch well above the waterline.

The method of mounting ports is similar to that used in the stern, except that panes are seated directly in heavy recessed plates and are secured by frames bolted directly to the outside panels (see fig. 4). Safety plates are of the same pattern as those used in the stern.

CONCLUSION

The Charles H. Gilbert's underwater viewing chambers appear to be successful, both from the point of view of effectiveness in observing fish and from that of structural design. The main defect of the stern chamber is noise and vibration due to the propeller shaft and resonance in the fuel tanks. A drawback of the bow chamber is that, because of space limitation, the observer must be at full length, an awkward position for photography. Aside from a small amount of rudder angle, the effect of the stern chamber on the vessel's performance is negligible. The effect of the bow chamber on vessel speed is difficult to assess because a new main engine and other alterations were added at the time the chamber was installed; the new bulbous bow, however, has improved vessel performance, especially in a head sea. The method of mounting viewing ports has proven satisfactory and no leakage or damage to ports has occurred.

LITERATURE CITED

Strasburg, Donald W. and Yuen, Heeny S. H. Progress in observing tuna underwater at sea. Journal du Conseil International pour l'Exploration de la Mer, vol. XXVI, No. 1. 1960.

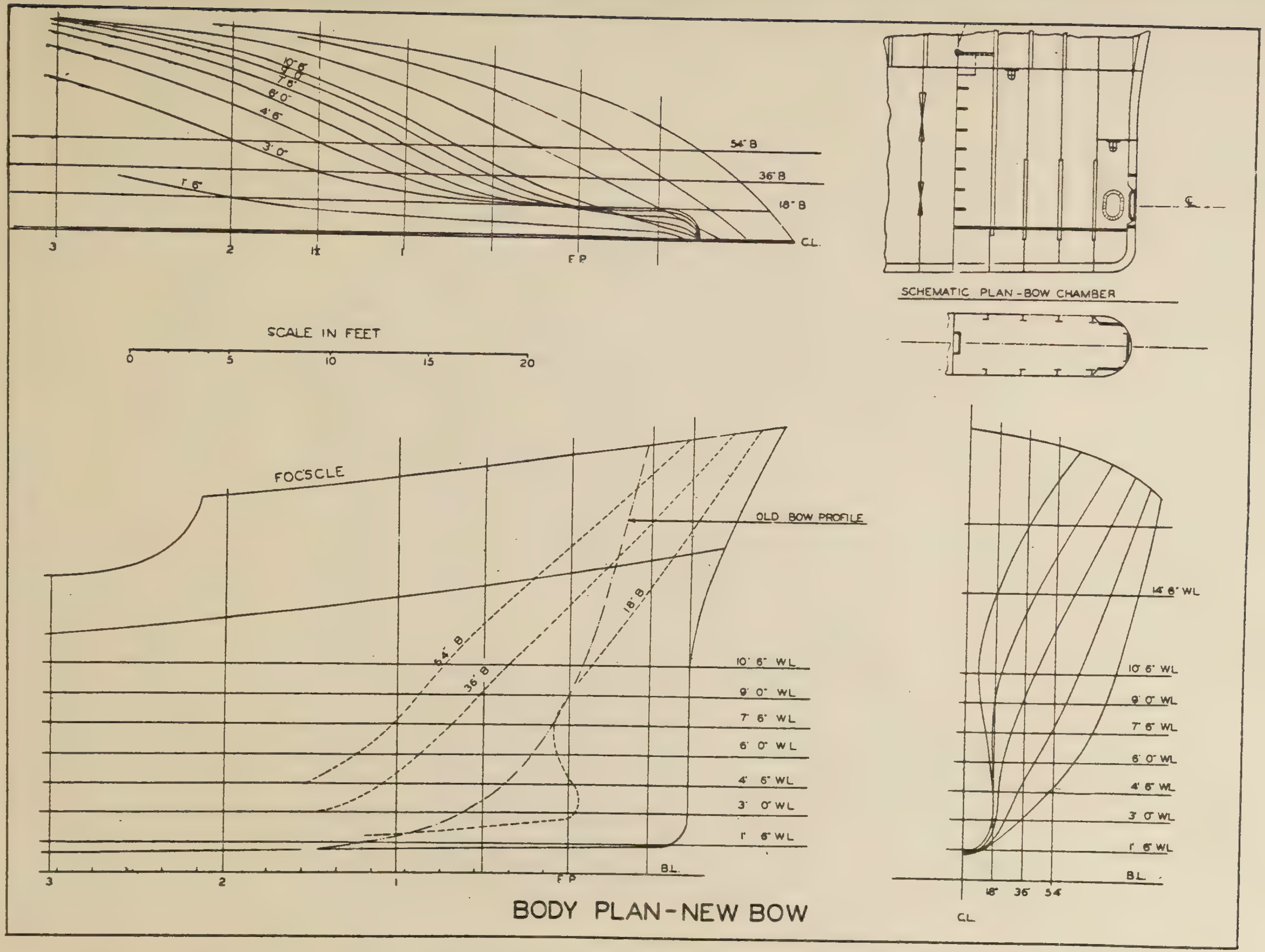

10' 6"
9' 0"
7' 6"
6' 0"
4' 6"
3' 0"
1' 6"
54" B
36" B
18" B
C.L.
3
2
1½
1
F.P.
SCHEMATIC PLAN - BOW CHAMBER
℄
SCALE IN FEET
0
5
10
15
20
FOC'SCLE
OLD BOW PROFILE
54" B
36" B
18" B
10' 6" WL
9' 0" WL
7' 6" WL
6' 0" WL
4' 6" WL
3' 0" WL
1' 6" WL
BL.
F.P.
BODY PLAN - NEW BOW
14' 6" WL
18"
36"
54"
CL.

Fig. 5.--Body lines and schematic plan of the Charles H. Gilbert's bow chamber.

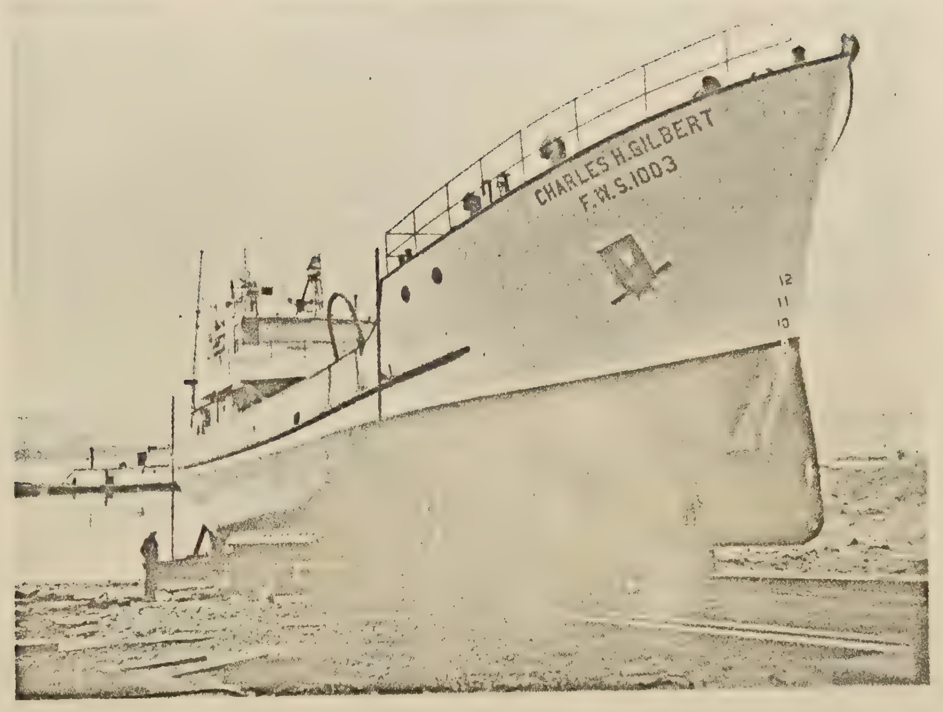

CHARLES H. GILBERT
F.W.S.1003
12
11
10

Fig. 6.--The Charles H. Gilbert after alteration in 1960, showing the new bulbous bow.

Published 1963 ICNAF. Fish marking
Special publication no 4, 1963
See HL publications -1963

DISPLAY COPY

INTERNATIONAL COMMISSION FOR THE NORTHWEST ATLANTIC FISHERIES

Serial No. 804
(B. Rept. 1)

Contribution No. 1

North Atlantic Fish Marking Symposium

Woods Hole, Mass., May, 1961

Note on the recovery rate of tagged skipjack, Katsuwonus pelamis, and the effects of handling

by John C. Marr[1]

ABSTRACT

Recovery rates of tagged skipjack were increased at least on order of magnitude through the use of dart tags, rather than loop or "spaghetti" tags. Increased recovery rates were presumably a reflection of increased survival rates resulting from decreased handling and time out of water. This conclusion is supported by evidence from attempts to establish skipjack in captivity. Such attempts were successful only when the skipjack were not directly handled and came in contact with no foreign objects except a barbless hook.

****** *** * ******************

Large-scale tuna tagging experiments commenced with the development of the plastic loop or "spaghetti" tag by Wilson (1953), following the earlier work of Alverson and Chenoweth (1951), Powell et al. (1952) and Schaefers (1952). This tag, a section of vinyl tubing, is applied through the muscle of the dorsal surface posterior to the second dorsal fin. The free ends are tied together after the tag is in place.

Subsequent improvements, as judged by increased recovery rates, have arisen from modifications in (1) materials and methods of application resulting in longer tag life, (2) tagging technique resulting in a reduction of the time during which the fish is out of water and in the amount of handling to which it is subjected and (3) materials and techniques resulting in a greater recognition rate of recaptured fish.

Modifications of the first type include the use of a clamp instead of a knot to secure the free ends of the tag, a tag core of monofilament nylon and the use of a different vinyl tubing capable of withstanding longer exposure to sea water (Schaefer, 1958).

Modifications of the second type include not measuring the length of the tagged fish, the use of an automatic clamping device for securing the free ends of the tag (Schaefer, 1958) and the use of a dart tag (Yamashita and Waldron, 1958). With the dart tag, oceanic skipjack (Katsuwonus pelamis) can be hooked, tagged and released in as little as four to seven seconds (Waldron, personal communication), as contrasted to 20 seconds for loop tags (Yamashita and Waldron, 1959). Modifications of the third type include more conspicuous tag color (Blunt and Messersmith, 1960; Schaefer, 1958) and an attractive reward system (Schaefer, 1958).

Skipjack are perhaps the most delicate of the tunas and have shown the greatest improvement in the recovery rate of tagged individuals as a result of reduction in tagging time and concomitant handling. For example, Blund and Messersmith (1960) report a recovery rate of 2.56% from 742 skipjack tagged with dart tags and 0.29% from 695 tagged with loop tags, in an experiment in which the two types of tags were applied to alternate fish in the

---

[1] Director, Honolulu Biological Laboratory, U.S. Bureau of Commercial Fisheries, P.O. Box 3830, Honolulu, Hawaii.

(over)

eastern tropical Pacific. Yamashita and Waldron (1958) report a recovery rate of 0.61% from 1961 skipjack tagged with loop tags in the vicinity of the Hawaiian Islands between 1954 and 1956. They also report a recovery rate of 9.15% from 8161 skipjack tagged with dart tags in the same area in 1957. Tagging mortality is apparently directly proportional to the time and handling required by tagging. The experience of Honolulu Biological Laboratory staff members in establishing skipjack in captivity clearly supports this conclusion.

Nakamura (MS) has recently reported on the establishment and behavior of skipjack in captivity. Initial attempts involved catching skipjack with barbless hooks, carrying them from the fishing racks to a bait well into which they were released, returning to port, removing the fish from the bait well and carrying them about 50 yards to an experimental tank. Ten attempts, involving 44 skipjack as well as two Euthynnus yaito and two Coryphaena hippurus, were made in this manner. All fish died within 48 hours. Various refinements, including carrying the fish in water-filled plastic bags and the use of thorazine, made no apparent difference in survival rate.

These difficulties led to the use of a portable tank. Skipjack caught with barbless hooks were lowered into the portable tank and allowed to shed the hook. When the ship returned to port, the portable tank was lifted (by crane) from the ship, carried to the experimental tank and lowered into it. Once in place, a hatch on the side of the portable tank was opened, the skipjack swam out into the experimental tank and the portable tank was removed. Thus, the fish were not directly handled and, in fact, did not come in contact with any foreign object except the barbless hook.

Two lots of skipjack have been introduced into the experimental tank in this manner. They exhibited little bruising and did not swim at high speeds nor bump into the tank walls, as did fish introduced in the original manner. Fish of the first lot survived for as long as 73 days and of the second lot for as long as 173 days. Food was taken on the ninth day by fish of the first lot and on the second day by fish of the second lot. After they began to feed, the fish were easily conditioned to an artificial stimulus for feeding. Death probably resulted from dietary insufficiencies, rather than other environmental conditions, and almost certainly not from handling.

Literature Cited

Alverson, Dayton L., and Harry H. Chenoweth. 1951. Experimental testing of fish tags on albacore in a water tunnel. U.S. Fish & Wildl. Serv., Com. Fish. Rev., vol.13, no.8, pp.1-7.

Blunt, C.E., Jr., and James D. Messersmith. 1960. Tuna tagging in the eastern tropical Pacific, 1952-1959. Calif. Fish & Game, vol.46, no.3, pp.301-369.

Nakamura, Eugene L. MS. The establishment and behavior of skipjack tuna (Katsuwonus pelamis) in captivity.

Powell, Donald E., Dayton L. Alverson and Robert Livingstone, Jr. 1952. North Pacific albacore exploration - 1950. U.S. Fish & Wildl. Serv. Fish. Leaf. 402, pp. 1-56.

Schaefer, Milner B. 1958. Report on the investigations of the Inter-American Tropical Tuna Commission for the year 1957. IATTA, Ann.Rept. for 1957. pp.31-79.

Schaefers, Edward A. 1952. North Pacific albacore tuna exploration - 1951. U.S. Fish & Wildl. Serv., Com. Fish. Rev., vol.14, no.5, pp.1-12.

Wilson, Robert C. 1953. Tuna marking, a progress report. Calif. Fish & Game, vol. 39, no.4, pp.429-442.

Yamashita, Daniel T., and Kenneth D. Waldron. 1958. An all-plastic dart-type fish tag. Calif. Fish & Game, vol. 44, no.4, pp. 311-317.

" " and Kenneth D. Waldron. 1959. Tagging of skipjack in Hawaiian waters. Pac. Sci., vol. XIII, no.4, pp. 342-348.

[illegible]

[illegible]

DISPLAY COPY

INTERNATIONAL COMMISSION FOR THE NORTHWEST ATLANTIC FISHERIES

Serial No. 874
(B. Rept. 1).

Contribution No. 50

The Use of Blood Group Characteristics in Studying Subpopulations of Fishes.

by John C. Marr 1)

and
Lucian M. Sprague 1)

Introduction

"It is one thing to recognize the existence of racial diversity and another to define it in terms of the underlying genetic facts." (Stern, 1960, p. 681).

The necessity of identifying population units (2/) within species of fishes that are the objects of commercial fisheries has long been recognized and has recently been summarized, Muzinić and Marr (In Press) as:

"The logical and practical reason for identifying population units is that such units may have their own characteristics of recruitment, growth, natural mortality, migration, behavior, etc., more or less independent of the characteristics of other population units within the same species. The need for studies of population units in a particular situation may arise from two sources:

(a) There exist variations in yield and/or heterogeneities in the characteristics of the catch for which the most likely explanation (hypothesis) is the existence of population units. (b) Management decisions have been made empirically for which it is necessary or desirable to provide understanding and thus confidence in the original decisions."

Methods of studying subpopulations have recently been reviewed (Marr, 1957) and may be grouped in four categories, according to the characteristics studied. These include (1) phenotypic qualities, (2) movements as revealed by tagging or marking, (3) vital statistics and (4) genetic characteristics.. Studies of phenotypic qualities (meristic and morphometric characteristics) and of movements revealed by tagging are too well known to require examples. The concept of identifying population units on the basis of vital statistics (rates of recruitment, death and growth) has only recently been proposed by Holt (as reported by Muzinic and Marr, In Press). The use of genetic characteristics, especially blood groups, is also a recent innovation. The use of phenotypic characteristics has a number of limitations. The characteristics used are frequently of the form of overlapping frequency distributions and, even with the more sophisticated techniques recently employed (see Royce, 1957, MS, for example), show (1) that the samples were not drawn from the identical universe and (2) the maximum possible mixing. Moreover, since the characteristics are susceptible of environmental modifications, the observed differences may relate to environments rather than to subpopulations. Frequently, if not generally, the samples are not drawn from spawning assemblages, so that real mixtures of subpopulations could remain undetected.

Tagging experiments require that fish be tagged and recovered. This is not only costly in time and effort, but effectively limits such experiments to areas in which there is an effective recovery mechanism (i.e., a fishery). Again, the tagging experiment is generally not performed on spawning assemblages, so that the question of interest is examined with less than maximum precision.

(footnotes 1 and 2 on bottom of page 2)

..../2

The use of vital statistics may, in fact, correspond more nearly to a definition of a subpopulation rather than to a tool for studying subpopulations. Their utility as a tool would be increased if they could be applied to spawning assemblages.

The limitations and advantages accruing from the use of blood groups in studying subpopulations will be considered in greater detail below. But a minor semantic difficulty must first be noted. The phenotypic characteristics referred to above are genotypic characteristics as modified by the environment; they are plastic. Numbers of vertebrae are an example of such a plastic phenotypic characteristic. Many quantitative genetic traits are subject to such environmental modification. There are also phenotypic characteristics which are not susceptible of environmental modification and bear a direct relationship to the genotype; they are non-plastic. Many qualitative genetic traits have direct regular genotype-phenotype relationships. Blood group phenotypes belong to the latter, non-plastic category.

Blood group systems

Blood groups are studied through the use of the antigen-antibody reaction. A number of compounds on or in the erythrocyte surface, and the soluble-specific substances (A of man, for example), constitute blood group substances. These substances are frequently present in certain individuals and lacking in others. The substances are probably polysaccharides and are certainly antigens. 3/.

Erythrocyte antigens and soluble specific substances have been found to be under genetic control in every animal in which this question has been studied. The various antigens which occur separately or together, in response to the segregation of genetic material at a single locus or genetic site, constitute a blood group system. Thus, antigens which are not genetically related belong to different blood group systems.

Antibodies, a constituent of plasma, occur either naturally or as products of the immune mechanism. Antibodies are reasonably antigen-specific and react in demonstrable ways with the appropriate antigen. The simplest and most common method of observing the reaction of antibody and erythrocyte antigen is the agglutination reaction. Thus, anti-x serum can be used to classify red blood cells according to the presence or absence of x (antigen).

The methods of pursuing such studies are, as already indicated, through the techniques of immunology. Initially, the investigator must acquire a set of antisera or reagents that will identify one or more of the blood groups present in the species of interest. Such reagents may be developed

---

(footnotes from page 1): 1/ Honolulu Laboratory, U.S. Bureau of Commercial Fisheries, P. O. Box 3830, Honolulu 12, Hawaii, U.S.A.

2/ A population unit may be defined as a fraction of a population that is itself self-sustaining. This is identical with the definition of subpopulation given by Marr (1957). Population unit, subpopulation and interbreeding population are here considered to be exact synonyms and are used interchangeably throughout.

(footnote from this page) 3/. Certain soluble-specific substances found in the body fluids might be considered to be non-antigenic.

by the introduction of red blood cells of the species being studied into other individuals of the same species, into individuals of other species or, more rarely, they may occur naturally in the same or other species. It has been found (Mäkelä, 1957; Bird, 1959) that extracts of the seeds of many legumes are very useful in this regard. The exact nature of the "antibodies" in the legume seeds is not known, but they are proteins, probably globulins (Boyd et al. 1958).

Exploratory classification of samples of the species under study will proceed, of course, simultaneously with the development of antisera. At some point the investigator will be satisfied that the antisera can identify one or more blood groups and will begin to examine series of samples from appropriate localities. Since erythrocytes are frequently difficult to preserve for any length of time, this may mean quite literally taking the tests to sea.

Through the use of this technique, samples of a subpopulation are not ordinarily classified according to the presence or absence of a single characteristic. In fact, most blood group systems are genetically quite complex, having more than two alleles; 6 - 9 alleles are not uncommon, and one blood group system in cattle has more than one hundred and fifty.4/ It follows, then, that samples are classified according to the frequency of presence or absence of several characteristics. Thus, in comparing samples, there still exists the problem (which fishery biologists constantly encounter) of making sample-size adequate to enable distinction between observational error and real differences between samples. But keep in mind that the differences, if any, relate to non-plastic rather than plastic phenotypes.

There is a further quality of genetic characteristics which adds great power to the use of this tool. In the presence random mating, 5/ and assuming no mutation or selection effects, the frequencies of alleles p, q...x will occur in proportions according to the expansion of the binomial. This condition will obtain after only one generation of random mating and will persist thereafter. This general concept is known as the Hardy-Weinberg Law. It follows, then, that single samples can be examined to determine whether or not they conform to this law. If a sample does not conform to the Hardy-Weinberg Law, it may be concluded that it was not drawn from an interbreeding population; i.e., it was composed of individuals of two or more interbreeding populations. If a sample does conform to the Hardy-Weinberg Law, the data are consonant with the hypothesis and it may be concluded that the sample was drawn from an interbreeding population.

Some examples

Examples may be drawn from observed frequencies of the phenotypes (and in this case, the genotypes) of the M-N blood group system in humans (Stern, 1960). The mode of inheritance is that of two alleles, $\underline{L}^M$ and $\underline{L}^N$, and the phenotypes, M, MN and N can all be identified serologically. Data on the observed frequencies of the these phenotypes in seven populations,

---

footnotes 4 and 5:

4/ It should be pointed out that, lacking genetic information, the recognition of a particular blood group system as a 2, 3, 4 or x allele system is an assumption.

5/ Random mating refers not to random mating between individuals, but rather to random combinations within a gene system.

...../4

the computed allele frequencies and the expected phenotype frequencies are given in Table 1. The frequency of allele $p\underline{L}^M$ is computed from

$$p\underline{L}^M = \frac{\overline{M} - 1/2\ \overline{MN}}{100}$$

and $q\underline{L}^N$ from

$$q\underline{L}^N = 1 - p\underline{L}^M$$

where $\overline{M}$ and $\overline{MN}$ are observed relative frequencies (percentages) in the populations.

The samples of the first six populations all conform closely to the Hardy-Weinberg Law and each may be considered to have been drawn froma distinct interbreeding unit or subpopulation. The seventh sample, however, does not conform to the Hardy-Weinberg Law and could not have been drawn from a distinct subpopulation ($P < 0.01$). The data were in fact obtained by combining, in equal parts, data from the first (Caucasian) and fourth (Eskimo) samples.

Table 1.

			Percentages of blood types			Allele Frequencies	
N	Population		M	MN	N	$p\underline{L}^M$	$q\underline{L}^N$
6129	Caucasian (U.S.)	obs.	29.16	49.58	21.26	0.540	0.460
		exp.	29.16	49.68	21.16	---	---
278	Negro (U.S.)	obs.	28.42	49.64	21.94	0.532	0.468
		exp.	28.35	49.89	21.86	---	---
205	Indian (U.S.)	obs.	60.00	35.12	4.88	0.776	0.224
		exp.	60.15	34.81	5.04	---	---
569	Eskimo (E. Greenland)	obs.	83.48	15.64	0.88	0.913	0.087
		exp	83.35	15.89	0.76	---	---
504	Ainu (Japan)	obs.	17.86	50.20	31.94	0.430	0.570
		exp.	18.45	49.01	32.34	---	---
730	Aborigine (Australia)	obs.	3.00	29.6	67.4	0.178	0.882
		exp.	3.17	29.26	67.57	---	---
1000	X	obs.	56	33	11	0.725	.275
		exp.	52.3	39.9	7.6	---	---

Another example that may represent a two-allele system has been given by Sinderman and Mairs (1959). They were able to classify individual herring in the Gulf of Maine as either C-positive or C-negative. Samples from different localities were characterized according to percent C-positive and those from the northeastern Gulf were found to have higher percentage (about 98%) of C-positive fish than samples from the southwestern Gulf (about 77%). If this is a regular two-allele system, the genotypes *CC* and *Cc* are classified as C-positive and *cc* as C-negative. Lacking the ability to distinguish between *CC* and *Cc* individuals, it is not possible to determine if these samples conform to the Hardy-Weinberg Law. The possibility exists that this C system is actually a much more complicated system, consisting of $\underline{C}_1$, $\underline{C}_2$, $\underline{C}_3$ ... $\underline{C}_x$ alleles. If this is so, the genotype $\underline{C}_x\ \underline{C}_x$ is identified as being C-negative; the remaining genotypic combinations are C-positive. This is a common genetic problem and its significance is only one of the degree to which phenotypes may be regularly related to allelic combinations.

..../5

Simililarly, Sprague and Vrooman (MS) have discovered a C system(6/)in the sardine of the northeastern Pacific. Although this is believed to be a multiple allele system and is known to be a multiple antigen system, the individual fish were classified only as C-positive or C-negative. Otherwise, the general remarks about the C system in herring apply here.

A two-allele system, A-a, has been found in sockeye salmon by Ridgway, Cushing and Durall (1958, 1961). It is possible to recognize all three phenotypes. Although the results presented are preliminary (and based upon relatively small samples), the samples from two spawning tributaries of the Columbia River conform to the Hardy-Weinberg Law, whereas samples from (1) the main Columbia River and (2) rivers from Kodiak Island to the Fraser River (combined) did not. The latter two samples, of course, would be expected, on the basis of other information, to be composed of individuals from several spawning populations. A fifth sample from rivers tributary to Bristol Bay (combined) did conform to the Hardy-Weinberg Law. It would be expected that this sample consisted of individuals from several spawning populations and Dr. Ridgway has informed us (personal communication) that additional studies indicate the existence of distinct populations within one of the rivers tributary to Bristol Bay. The original conclusion of homegeneity within the rivers tributary to Bristol Bay is thus modified.

A blood group system designated Tgl - Tg2 - O has been found in albacore tuna by Suzuki, Morio and Mimoto (1959). We interpret their data to indicate a blood group system with three alleles, analogous to the human A-B-O blood group system. Suzuki et al. (1959) give data for samples from the Pacific Ocean in the general area southeast of Honshu and from the Indian Ocean largely from the general area southwest of Sunda Strait. The striking differences between samples from these two areas in phenotype frequencies were noted, but the question of whether or not the samples from each area were drawn from an interbreeding population was not examined. It is of interest to do so.

According to the Hardy-Weinberg Law, if the samples were drawn from an interbreeding population, then the following relationship obtains:

$$\underline{Tg1} + \underline{Tg2} + \underline{O} = 1$$

where

$$\underline{Tg1} = 1 - \sqrt{\overline{O} - \overline{Tg^2}} \quad ,$$

$$\underline{Tg^2} = 1 - \sqrt{\overline{O} - \underline{Tg^1}}$$

$$\underline{O} = \sqrt{\overline{O}}$$

Substituting the Pacific Ocean data

$$0.04 + 0.71 + 0.27 = 1.02$$

For the Indian Ocean data, however

$$0.39 + 0.55 + 0.30 = 1.24$$

Thus, it may be concluded that the Pacific Ocean samples were drawn from a single interbreeding population, but that the Indian Ocean samples were drawn from a mixture of two or more interbreeding populations. There is, incidentally, other evidence (from tagging experiments, for example) that the albacore of the North Pacific constitute a single interbreeding population. A similar inference (based on much less evidence) is possible about albacore of the South Pacific.

Footnote 6/: The use of the same letter to designate blood group systems in different species does not indicate, barring a specific statement to the contrary, the existence of the identical or even similar blood group in the different animals. This practice arises because of the small number of letters in the alphabet and the tendency to assign letters beginning with the first letter of the alphabet.)

...../6

Another three-allele A-B-O analog, termed $\underline{S}_1$-$\underline{S}_2$-$\underline{O}$, has been reported in the spiny dogfish in the Gulf of Maine by Sinderman and Mairs (MS)7/. Their data conform to the Hardy-Weinberg Law, indicating that their samples were drawn from a single inter-breeding population. An interesting aspect to their work was the comparison of the blood group types of pregnant females and their unborn pups. The results of this comparison were consonant with a three-allele system.

A final example is that of the sardine B system (Sprague and Vrooman, MS), which by detailed serological analysis suggests a system in which at least four alleles are segregating. In practice, it was possible to recognize only three phenotypes and one of them occurred so rarely (.001) as to be negligible. This particular system affords a good example of the difficulties which may be encountered in working with complicated blood group systems. The work of Sprague and Vrooman (MS) is also of interest in that the C system (see above) and the B system were shown to be independent.

We have not considered the statistical methodology pertinent to these problems. References to three previous works may be helpful. Applications of Chi-square have been given by Race and Sanger (1958). An introduction to the methods of gene frequency calculations and the application of Chi-square has been presented by Mourant (1954). In cases where Chi-square is not pertinent, the $\underline{Z}$ test for the significance of the difference between means are useful (see, for example, Freund et al. 1960).

Application to fishery problems

On a practical basis, the general "subpopulation problem" in fishery biology involves (1) the definition and recognition of the interbreeding unit and (2) the delineation of its geographic range, including its spawning range and its total range.

This general problem is usually encountered in more specific form and hyperthetical examples of three common situations will be considered. (While the examples given above on the occurrence of blood group systems in fish are pertinent, data on human blood group systems will be used illustratively only because they are much more extensive and not because of any superiority).

First, are the fish at Area A (which is, say the area of a fishery) from a single subpopulation or from more than one? Each of the first six examples in Table 1 may be considered to be analogous to fish samples drawn from six area A's. On the basis of the MN blood group, it may be said that each of these samples represents an interbreeding population. The seventh sample, however, does not conform to Mendelian expectations and must represent individuals from two or more subpopulations. This examination of the data will not indicate that these particular data were made by equal contributions from two of the other groups in the table.

In the case where heterogeneity is found, the subsequent steps taken to determine exactly how many populations are involved and their distributions, are difficult to generalize, since they will be determined by the real situation obtaining and how much the investigator knows about it.

Second, are the fish from discrete areas B and C, which are both fishery areas, of the same population or of distinct subpopulations ? As an example, consider the data of Table 1 for Eskimo and Aborigine. These have each been demonstrated to represent an interbreeding population. They are so different it is obvious that they represent two distinct populations, rather than two samples of a single population.

Footnote 7/: The use of subscripts in the designation of the antigens of the spiny dogfish and of the albacore is probably unfortunate, since there is a conflict in this terminology with the accepted notation for regular subtyping relationships such as are found in the A_1, A_2 series of the A-B-O blood group.

But suppose that, instead of Eskimo and Aborigine, samples from the two areas were represented by Caucasian and Negro. It is obviously impossible to distinguish between these two population units on the basis of the M-N blood group system. However an additional set of allele frequency estimates (Table 2) for a genetically independent blood group system, the A -B-0 system, demonstrates that these two samples are, in fact, from distinct population units ($P<0.01$). (Had these A-B-0 data, pooled, been drawn from a single area, as in the first hypothetical example, it would only have been possible to conclude that two or more subpopulations were present. The exact number could not have been specified without additional data).

This particular example emphasizes the obvious: The greater the number of genetically independent blood group systems by which the organisms may be classified, the more powerful will be the method.

Third, if fish from discrete Areas D and E, which are non-fishery areas, are known to be separate subpopulations and if fish from these separate areas (subpopulations) mingle in Area F, which is a fishery area, what is the relative contribution of each subpopulation to the fishery area? An example is found in Table 1, if the Caucasian data are considered to represent Area D, the Eskimo data Area E and the X data Area F. This is a straightforward problem, since there is a unique combination of the observed blood group frequencies in Areas D and E which will yield those observed in Area F.

Table 2. Frequencies of A-B-0 blood Groups in two human populations comparible to those represented in Table 1. From Boyd (1939).

N	Population	Percentage of blood types				Allele frequencies		
		0	A	B	AB	$p=I^A$	$q=I^B$	$r=I^O$
500	Negro (U.S.)	47.0	28.0	20.0	5.0	.181	.133	.686
1708	Caucasian (U.S.)	44.0	37.9	13.2	4.5	.240	.094	.668

Advantages and disadvantages

The advantages and disadvantages of the use of blood group systems in the study of subpopulations of fish may be summarized.

Advantages:

1. The characteristics studied are genetic.
2. Not only can samples be compared, but single samples can be examined with respect to whether or not they were drawn from a single subpopulation.
3. The statistical procedures involved are simple.
4. Recaptures (or a fishery) are not required.

Disadvantages:

1. Blood preservation may be a problem. If it is, the method must be taken to sea.
2. Developing reagents may be difficult and time-consuming.
3. In order for the full power of the technique to be realized, blood group systems must be identified and it must be possible to recognize one more phenotype than the number of recognized alleles. (This provides the degree of freedom necessary for Hardy-Weinberg analysis.)

It is apparent to us, and, we hope, to others that the use of blood group systems in fish constitutes an extremely useful and powerful tool in the solution of problems involving the definition and recognition of interbreeding populations. Examples of such problems have been given

It also seems to us that, in the long run, the use of this tool will lead to more important results in the understanding of populations of fish in nature, especially in three ares:(1) the genetics (in the classical sense) of fish; (2) the interaction of fish and environment leading to isolation of population units and the nature of these isolating mechanisms; and (3) population genetics.

Summary

The necessity for studying population units of fish, the desiability of using genetic characteristics in such studies, and the nature of blood group systems are briefly reviewed.

Examples are drawn from the M-N and A-B-0 blood groups in man. Examples are given of blood group systems recently found in several bony fish, including westerb Atlantic herring, Northeastern Pacific sardine, Sockeye salmon, albacore tuna and in one elasmobranch, the spiny dogfish.

Illustrations are given of how data on blood group systems are useful in attacking the kinds of problems encountered by fishery biologists, It is suggested that such data will also contribute to the solution of broader problems.

Literature Cited

Bird, G,W.G.
1959 Haemaglutinins in seeds. Brit. Med. Bull., Vol. 15, no. 2, pp. 165-8

Boyd, W.C.
1939 Blood groups. *Tabulae Biologicae*, vol. 17, pp. 113-240.

Boyd, W.C., D.L. Everhart and M.H. McMaster,
1958. The anti-N lectin of *Bauhinia purpurea*. J. Immunol. vol. 81, no. 5, pp. 414-20.

Freund, J.E., Paul Livermore and Irwin Miller,
1960 Manual of experimental statistics. Prentice-Hall Inc., New Jersey, pp. viii + 132.

Mäkelä, O.
1957 Studies in hemagglutinins of Leguminosae seeds. Thesis supplement no II. Ann. Med. exp. Fenn., vol. 35, pp. 133

Marr, John C.
1957 The problem of defining and recognizing subpopulation of fish. pp. 1-6 *In* Contributions to the study of subpopulations of fish. U.S. Fish & Wildl. Serv., Spec. Sci. Rept. : Fish., no. 208, pp. 129

Mourant, A.E.
1954 The distribution of the human blood groups. Blackwell Scientific Publications, Oxford, pp. xxi + 437.

Mužinić, R., and J.C. Marr
In Press. Population indentification. Rept. Sect. 1. *In* FAO, Proc. World Sci. Meet. Biol. Sardines & Rel. Species. Vol. 1.

Race, R.R., and L.R. Sanger
1958 Blood groups in man. 3rd Ed. Blackwell Scientific Publications , Oxford, pp. xix + 377

Ridgway, G.J., J.E. Cushing and G.L. Durall
1958 Serological differentiation of populations of sockeye salmon, *Oncorhynchus nerka*. U.S. Fish & Wildl. Serv., Spec. Sci. Rept.: Fish., no. 257, pp. 9

1961 Serological differentiation of populations of sockeye salmon, *Oncorhynchus nerka*. Int. N. Pac. Fish. Com., Bull. no.3, pp. 5-10.

Royce, William F.
1957 Statistical comparison of morphological data. pp. 7-28 *In* Contributions to the study of subpopulations of fish. U.S. Fish & Wildl. Serv., Spec. Sci. Rept.: Fish., no. 208 pp. 129.

MS. A morphometric study of yellowfin tuna, *Thunnus Albacores* (Bonnaterre).

Sinderman, Carl J., and Donald F. Mairs
1959 A major blood group system in Atlantic sea herring. Copeia, 1959, no. 3, pp. 228-32.

MS. A blood group system for spiny dogfish, *Squalus acanthias*.

Sprague, Lucian M., and Andrew M. Vrooman
MS. A racial analysis of the Pacific sardine (*Sardinops caerulea* based on studies of erythrocyte antigens.

Stern, Curt
1960 Principals of human genetics. 2nd Ed. W.H. Freeman & Co., San Francisco, pp. x + 753.

Suzuki, Akimi, Tadao Morio and Koichi Mimoto
1959 Serological studies of the races of tuna. II. Blood group frequencies of the albacore in Tg-System. Part I. Comparison of the Indian and the northwestern Pacific Ocean. Rept. Nankai Reg. Fish. Res. Lab. no 11, pp. 17-23.

SUMMARY

The necessity for studying population units of fish, the desirability of using characteristics in such studies, and the nature of blood group systems are briefly reviewed.

Examples are drawn from the M-N and A-B-O blood groups in man. Examples are given of blood group systems recently found in several bony fish, including western Atlantic herring, northeastern Pacific sardine, sockeye salmon, albacore tuna and in one elasmobranch, the spiny dogfish.

Illustrations are given of how data on blood group systems are useful in attacking the kinds of problems encountered by fishery biologists. It is suggested that such data will also contribute to the solution of broader problems.

DISPLAY COPY

SHORTER COMMUNICATIONS

Collection and descriptions of juvenile tunas from the central Pacific*

WALTER M. MATSUMOTO
U.S. Bureau of Commercial Fisheries, Honolulu, Hawaii

(*Received* 21 *February*, 1961)

Abstract—Collections of juvenile tunas during the period 1951–60 from the central Pacific are recorded. Juveniles of *Neothunnus macropterus* (TEMMINCK and SCHLEGEL), *Katsuwonus pelamis* (LINNAEUS), and *Auxis* sp. are described and figured. Initial results with the British Columbia midwater trawl, as modified for collecting tuna forage organisms and juvenile tunas, suggest that this trawl has considerable promise as a collecting device. Its ability to catch juvenile tuna appears much greater than that of the 10 ft Isaacs-Kidd midwater trawl.

ALTHOUGH much has been learned in recent years about the biology of adult tunas, we still have very little information concerning the occurrence, distribution, and habits of their postlarval and juvenile stages. This lack is due mainly to poor success in collecting the young with the methods hitherto used, i.e., dipnetting at night-light stations, midwater trawling with small and medium-sized nets, seining with tuna bait nets, and searching the stomach contents of adult tunas and other pelagic fishes. Most of the juveniles recorded in the litertature have been reported from scattered localities and have come either from the stomachs of pelagic fishes (KISHINOUYE, 1919, 1923, 1924, 1926; INANAMI, 1942; MARR, 1948; ECKLES, 1949; SHIMADA, 1951a; YABE, ANRAKU and MORI, 1953; YABE *et al.*, 1958) or from dipnetting at nightlight stations (SCHAEFER and MARR, 1948a, 1948b; WADE, 1949, 1950; SHIMADA, 1951b; KLAWE and SHIMADA, 1959). Since tuna juveniles are taken sporadically, generally in small numbers, it is important that all known captures be recorded so that the information will be available to investigators.

As a part of their research on the biology of the tunas, staff members of the Honolulu Biological Laboratory (HBL), United States Bureau of Commercial Fisheries, have been trying since 1951 to collect young tunas with only moderate success (TABLE 1). Recently, during the period 20 October to 8 November 1958, a series of test hauls was made with a British Columbia midwater trawl (BARRACLOUGH and JOHNSON, 1956), modified with a cod-end of $\frac{1}{4}$ in. mesh. The results (TABLE 2)

---

* Published by permission of the Director, U.S. Bureau of Commercial Fisheries.

Deep-Sea Research. 1961.
vol. 8, no. 3/4, p. 279-285.

INTERIOR
SERVICE

indicate that this trawl will be an effective instrument for collecting juvenile tunas.

Two types of hauls, horizontal and 3-step oblique, were made. In the first the trawl was lowered to the desired depth, where it was towed horizontally for 1 hr. In the second the trawl was lowered to the desired depth (usually 300–350 ft) and then towed horizontally for 20 minutes at each of three levels : 300, 200 and 100 ft. The results (Table 2) provided several valuable bits of information. First, it was evident that the 3-step oblique pattern gave a higher percentage of hauls in which juvenile tunas were taken (57%) than did the horizontal pattern (25%). Second, a statistical comparison using the Mann-Whitney *U* test (SIEGEL, 1956) did not indicate any significant difference (one-tailed $p = 0{\cdot}473$) in juvenile tuna captures between hauls made at night (2000 hr. local time) and in the day (0800 hr. local time). Third, the British Columbia trawl took juveniles up to 52·5 mm long in mid-ocean, whereas earlier captures of fish this size were all near land. Juvenile tuna were taken by the trawl at distances from the nearest land of 280 to 540 miles, the latter being the greatest distance from land at which the gear was used.

Since no day–night difference was found in the catches, data for all 3-step oblique hauls were combined for comparing performance of the British Columbia trawl with that of a 10 ft. Isaacs-Kidd trawl which had been used by HBL for collecting young tuna (Table 3). The upper section of TABLE 3 shows that the sampling conditions for the two trawls were comparable, except for the depth of the haul. This difference is corrected, however, by expressing the catch in terms of juveniles per unit of water strained between the surface and the 300 ft. depth. A comparison made on this basis shows that the British Columbia trawl caught 43·6 per cent more juveniles than the 10 ft. Isaacs-Kidd trawl. If we assume that juvenile tunas were equally abundant in the area where both cruises were made, and there are no strong reasons for believing otherwise, then the higher catch made with the British Columbia trawl must be due to the greater efficiency of the trawl for this purpose. This higher efficiency was probably due to the larger mouth opening (111·7 m^2 in the British Columbia trawl as against 8·2 m^2 in the 10 ft. Isaacs-Kidd trawl) and, to some extent, to the speed of hauling (average of 3 knots as against 5 knots). Since juveniles of the sizes taken in trawls (up to 52·5 mm) are probably already fairly rapid swimmers, they would be expected to be able to dodge a small net more easily than a large one. If the smaller net were hauled at high speed to overcome this dodging, it would very likely increase net noise and luminescence to such an extent that the fish would become aware of the net early enough to avoid it. Consequently, it is conceivable that a net with a large mouth opening, hauled at a slower speed, may be much more effective in capturing juvenile tunas. The higher catches obtained with the British Columbia trawl appear to support this hypothesis.

Of the juvenile tunas in the HBL collection, species identifications have been made for *Neothunnus macropterus* (TEMMINCK and SCHLEGEL) and *Katsuwonus pelamis* (LINNAEUS). A num berof juveniles recognized as *Auxis* could not be assigned to species (see later discussion). Three unidentified specimens, although recognized as scombrid, could not be identified either to genus or species because they were badly damaged.

Juvenile *N. macropterus* (FIG. 1) are characterized by a relatively deep body; a short snout, equal to or less than the diameter of the eye; a completely black first dorsal fin, the edge of which forms a convex outline; and the absence of pigmentation on the thoracic and abdominal areas. Other pigmentation on the body includes heavy concentrations or bands along the mid-lateral line and along the dorsal edge. Dorsal to the mid-lateral line are faint patches of pigment which develop into five or six vertical bars on larger juveniles.

As in adult *N. macropterus*, a 22·6 mm juvenile cleared and stained in alizarin red *S* has 39 vertebrae (18 precaudals and 21 caudals), and the first haemal spine is similar to the spines following it. The gillrakers on the first arch are not fully developed in this specimen (2 + 16), but the 46 mm specimen in FIG. 1 already has enough gillrakers (7 + 21) for positive identification. The 21 gillrakers on the lower limb of the arch is identical with the number found in the adult (usually 20–21).

Four other species of thunnids have been recorded from the central Pacific where our juveniles were obtained. Since the possibility exists that our juveniles may be any one of these, it is important that any similarities or differences be examined. *Parathunnus sibi* (TEMMINCK and SCHLEGEL), which generally has 18 or 19 gillrakers on the lower limb of the first gill arch, was eliminated, since our 46 mm juvenile already has 21 gillrakers. Two other speices, *Thunnus orientalis* (TEMMINCK and SCHLEGEL) and *T. thynnus* (LINNAEUS), which may be synonymous, were eliminated because they generally have 22–23 gillrakers on the lower limb. The albacore, *T. germo* (LACÉPÈDE), is the only species having a gillraker count for the lower limb (generally 20, often 21) similar to that of our juvenile, but it was eliminated on the basis of the shape of the first haemal spine (YABE *et al.*, 1958).

Table 1. *Record of juvenile tuna collection in the central Pacific by the Honolulu Biological Laboratory by gear and methods other than the British Columbia midwater trawl*

Date	*Latitude* *Longitude*	*Katsuwonus pelamis*	*Neothunnus macropterus*	*Auxis sp.*	*Uniden-tified*	*Total*	*Fork length* (mm)	*Method of capture*
25 April 1951	2° 11·0′ N 153° 08·0′ E (South of Caroline Is.)	5	0	0	0	5	39–44	Dipnet[1]
3 May 1951	6° 20·5′ N 162° 22·0′ W (Kingman Reef, Line Is.)	34	0	0	0	34	20–34	Dipnet
25 May 1951	2° 51·0′ N 157° 03·0′ W (South of Caroline Is.)	6	0	0	0	6	23–55	Dipnet[1]
30 May 1951	5° 18·0′ N 159° 49·0′ E (South of Caroline Is.)	12	0	0	0	12	21–49	Dipnet[1]
20 June 1951	2° 01·5′ N 171° 37·0′ W (Near Phoenix Is.)	4	2	0	0	6	16–19	Dipnet
21 June 1952	5° 56·0′ N 139° 26·0′ W (Mid-ocean)	1	0	0	0	18	18	6 ft. beam trawl[2]
9 April 1953	20° 35·0′ N 157° 32·0′ W (Hawaiian Is.)	1	0	0	0	1	18	1-M ring trawl[2]
3 June 1954	1° 44·0′ N 158° 15·0′ W (North of Jarvis Is.)	0	0	0	1	1	<20	6 ft. Isaacs-Kidd trawl[2]
1 February 1955	29° 56·0′ N 179° 28·0′ E (Northwest of Kure Is.)	0	0	0	2	2	20; 60	10 ft. Isaacs-Kidd trawl[2]
5 February 1956	6° 20·5′ N 162° 22·0′ W (Kingman Reef, Line Is.)	5	0	0	0	5	45–58	Dipnet
26 September 1956	0° 02·0′ N 159° 50·0′ W (North of Jarvis Is.)	1	0	0	0	1	22	10 ft. Isaacs-Kidd trawl[2]
27 January 1958	8° 49·0′ S 140° 04·5′ W (Near Marquesas Is.)	7	0	0	0	7	23·5–34	Stomach of *N. macropterus*
28 February 1958	7° 42·0′ S 140° 10·0′ W (Near Marquesas Is.)	3	0	3	0	6	31–52	Stomach of *N. macropterus*
22 May 1959	20° 47·0′ N 157° 28·0′ W (Hawaiian Is.)	1	0	0	0	1	49	Bait seine[3]
13 August 1959	(Vicinity of Oahu, Hawaiian Islands. Position not available)	6	1	7	0	14	30–73	Regurgitated by *K. pelamis*[3]
Totals		86	3	10	3	102		

[1] Ego and Otsu, 1952.
[2] King and Iversen (unpublished manuscript).
[3] Commercial live-bait fishing vessel, M.V. *Bonito*.

Table 2. *Results of trawling for juvenile tunas with a modified British Columbia midwater trawl on cruise 47 of the* Hugh M. Smith[1]

Sta. No	*Date*	*Latitude*	*Longitude*	*Type of haul*	*Maximum depth of tow* (ft.)	*Zone time*[2]	*Katsuwonus pelamis*	*Neothunnus macropterus*	*Auxis sp.*	*Total*	*Fork length* (mm)
19	20 October	15° 20′ N	153° 40′ W	Horizontal	450	2107	0	0	0	0	—
32	27 October	0° 02′ S	149° 32′ W	Horizontal	310	1315	0	0	0	0	—
33	27 October	0° 01′ N	149° 44′ W	Horizontal	300	2010	0	0	0	0	—
37	30 October	4° 58′ S	150° 00′ W	Horizontal	300	0845	12	0	0	12	14·5–26
38	30 October	4° 58′ S	149° 52′ W	Horizontal	740	1312	0	0	0	0	—
39	30 October	4° 57′ S	149° 56′ W	Horizontal	320	2013	0	0	0	0	—
41	31 October	5° 00′ S	150° 00′ W	Horizontal	40	0807	0	0	0	0	—
44	31 October	5° 01′ S	150° 00′ W	Horizontal	30	2025	0	0	0	0	—
46	1 November	5° 00′ S	149° 58′ W	3-step oblique	340	0845	7	0	0	7	10–30
47	1 November	3° 38′ S	149° 56′ W	3-step oblique	350	2012	0	0	0	0	—
49	2 November	2° 09′ S	149° 47′ W	3-step oblique	320	0843	3	0	0	3	23–29
51	2 November	0° 44′ S	149° 46′ W	3-step oblique	320	2013	4	0	4	8	18·5–52·5
53	3 November	0° 37′ S	149° 58′ W	3-step oblique	310	0838	3	0	0	3	19·9–21·7
56	4 November	1° 56′ N	150° 09′ W	3-step oblique	310	1030	0	0	0	0	—
58	4 November	2° 56′ N	150° 03′ W	3-step oblique	340	2013	1	0	0	1	13·9
60	5 November	4° 28′ N	150° 29′ W	3-step oblique	350	0820	0	0	0	0	—
62	5 November	6° 06′ N	150° 28′ W	3-step oblique	340	2017	1	2	0	3	14·6–22·6
64	6 November	7° 39′ N	150° 16′ W	3-step oblique	320	0823	1	0	0	1	24·1
66	6 November	9° 08′ N	150° 03′ W	3-step oblique	350	2005	0	0	0	0	—
68	7 November	10° 40′ N	149° 52′ W	3-step oblique	340	0825	0	0	0	0	—
70	7 November	12° 13′ N	149° 56′ W	3-step oblique	350	2015	1	0	0	1	6·8
72	8 November	13° 53′ N	150° 01′ W	3-step oblique	450	0817	0	0	0	0	—
	Totals						33	2	4	39	

[1] Research vessel of the U.S. Bureau of Commercial Fisheries.

[2] Starting time for each tow.

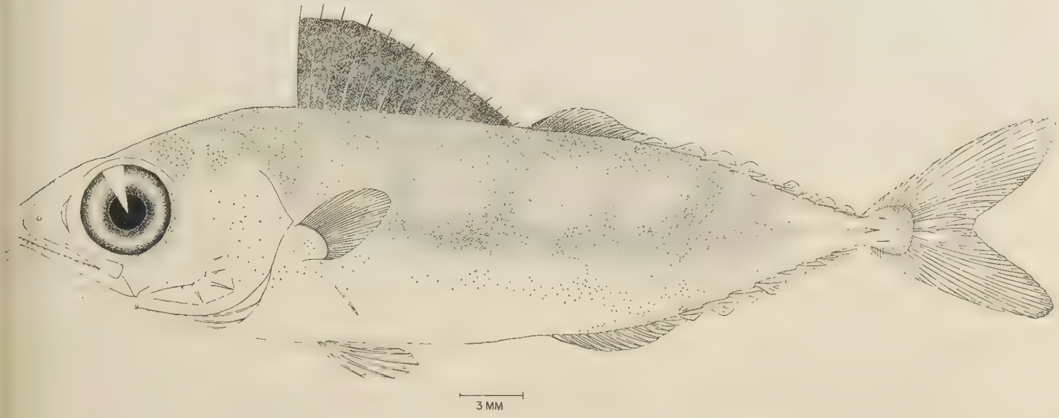


Fig. 1. A 46 mm *Neothunnus macropterus* regurgitated by adult *Katsuwonus pelamis*, off the island of Oahu, Hawaiian Islands.

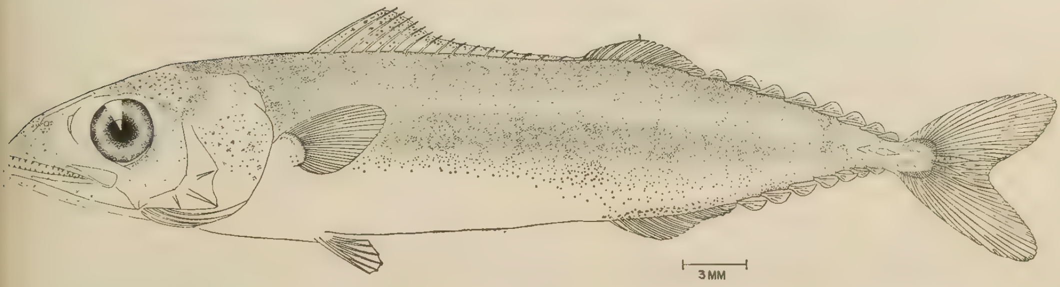


Fig. 2. A 47 mm *Katsuwonus pelamis* captured in dipnet at Kingman Reef, Line Islands.

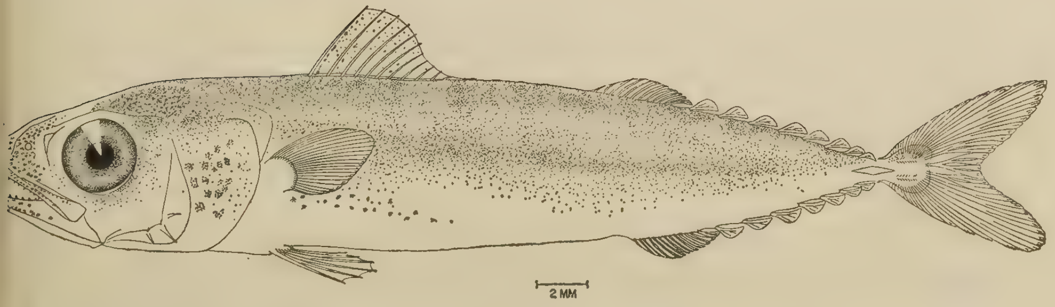


Fig. 3. A 39 mm *Auxis* sp. captured in a modified British Columbia midwater trawl at 0° 44′ S, 149° 46′ W.

YABE's study indicates that *T. germo* as small as 124 mm (standard length) can be identified by this spine, which appears laterally compressed. I examined one of YABE's specimens measuring 184 mm and noted that the width of the flat first haemal spine was nearly twice that of the second. The second spine and those following it were normal, as in other tunas. In our specimens the first haemal spine was not compressed but was similar to the second spine. Thus, on the basis of the number of gill-rakers on the lower limb of the first gill arch and the shape of the first haemal spine, it seems reasonable to assume that our juveniles are *N. macropterus.*

Table 3. Comparison of the performance of the British Columbia and 10-foot Isaacs-Kidd midwater trawls in collecting juvenile tunas

	British Columbia trawl	10 *ft. Isaacs-Kidd trawl*[1]
Trawling data :		
Vessel[2] and cruise number	*Hugh M. Smith* 47	*Hugh M. Smith* 35
Area : latitude	14°N – 5 °S	10 °N – 5 °S
longitude	150 °W	143 °W – 160 °W
Dates	20 Oct. – 8 Nov. 1958	15 Aug. – 1 Oct. 1956
Depth of haul	0 – 350 ft.	0–600 ft.
Type of haul	1-hour 3-step oblique	1-hour oblique
Number of hauls	14	13
Total volume of water strained (500,000 m^3)	18·73	0·99[3]
Results :		
Total juveniles captured	27	1
Juveniles per 500,000 m^3 of water strained	1·44	1·01

[1] Data for the Isaacs-Kidd trawl from KING and IVERSEN (Unpublished manuscript).
[2] Research vessel of Honolulu Biological Laboratory, U.S. Bureau of Commercial Fisheries.
[3] Calculated on the basis of a sampling depth of 0–300 ft for comparison with the British Columbia trawl.

Juvenile *K. pelamis* (FIG. 2) are easily identified by the characteristic pigmentation of the first dorsal fin and its concave outline, the moderately long snout, and the number of vertebrae. The first dorsal fin has scattered chromatophores on the first 3 or 4 interspinal membranes and along the distal edge of the remaining membranes. The only other genus in which the juveniles are known to have the first dorsal fin shaped like that of *K. pelamis* is *Euthynnus* (SCHAEFER and MARR, 1948a; WADE, 1950; MEAD, 1951; MATSUMOTO, 1959). In *Euthynnus*, however, the first dorsal fin is either completely or almost completely pigmented, as in *N. macropterus.* Furthermore, unlike *Euthynnus* and *N. macropterus*, juveniles of *K. pelamis* do not develop vertical bands of pigmentation on the dorsal half of the body during the early stages of growth. The snout, measured from its tip to the anterior edge of the eye, is much greater than the diameter of the eye.

Examination of 4 cleared and stained juveniles (19, 27, 33, and 52 mm) revealed 41 vertebrae (20 precaudals and 21 caudals), which is definitive for *K. pelamis.*

The young of *Auxis* (FIG. 3) are easily recognized by the narrow body, the widely separated first and second dorsal fins, and the very light pigmentation of the first dorsal fin. In addition, all specimens have a black spot at the isthmus, a characteristic seen only in one other genus, *Euthynnus* (MEAD, 1951; MATSUMOTO, 1958, 1959). In juvenile *Euthynnus* however, the first and second dorsal fins are continuous.

It is known that two species of *Auxis*, the short-corseleted *A. thazard* (LACÉPÈDE) and the long-corseleted *A. thynnoides* (BLEEKER), occur in the Pacific (KISHINOUYE, 1923; FOWLER, 1938; WADE, 1949; MATSUMOTO, 1960). Although the adults of this species are separable by corselet morphology, this character is useless for separating juveniles below 200 mm in length, because the corselet scales are not fully developed. Consequently no definite species identification of our *Auxis* specimens has been made.

REFERENCES

BARRACLOUGH, W. E. and JOHNSON, W. W. (1956) A new midwater trawl for herring. *Bull. Fish. Res. Bd., Canada,* **10** (104), 1–25.

ECKLES, H. H. (1949) Observations on juvenile oceanic skipjack (*Katsuwonus pelamis*) from Hawaiian waters and Sierra mackerel from the eastern Pacific. *Fish. Bull., U.S.* **51** (48), 245–250.

EGO, K. and OTSU, T. (1952) Japanese tuna-mothership expeditions in the western equatorial Pacific Ocean. *Comm. Fish. Rev.* **14** (6), 1–19.

FOWLER, H. W. (1938) The fishes of the George Vanderbilt South Pacific Expedition, 1937. *Monogr. Acad. Nat. Sci. Philadelphia* **2**; 31–33, 253, 277.

INANAMI, Y. (1942) Small skipjack caught at Truk. *South Sea Fish. News* **6** (1), 7.

KING, J. E. and IVERSEN, R. T. B. Midwater trawling for forage organisms in the central Pacific. (Unpublished manuscript).

KISHINOUYE, K. (1919) The larval and juvenile stages of the Plecostei. *Proc. Sci. Fish. Assoc., Tokyo* **3** (2), 49–53.

KISHINOUYE K. (1923) Contributions of the comparative study of the so-called scombroid fishes. *J. Coll. Agric., Tokyo* **8** (3), 293–475.

KISHINOUYE K. (1924) Observations on skipjack fishing grounds. *Proc. Sci. Fish. Assoc., Tokyo* **4** (2), 87–92.

KISHINOUYE, K. (1926) An outline of studies of the Plecostei (tuna and skipjack) in 1925. *Proc. Sci. Fish. Assoc., Tokyo* **4** (3), 125–137.

KLAWE, W. L. and SHIMADA, B. M. (1959) Young scombroid fishes from the Gulf of Mexico. *Bull. Mar. Sci. Gulf Caribb.* **9** (1), 100–115.

MARR, J. C. (1948) Observations on the spawning of oceanic skipjack (*Katsuwonus pelamis*) and yellowfin tuna (*Neothunnus macropterus*) in the Northern Marshall Islands. *Fish. Bull., U.S.* **51** (44), 201–206.

MATSUMOTO, W. M. (1958) Description and distribution of larvae of four species of tuna in central Pacific waters. *Fish. Bull., U.S.* **58** (128), 31–72.

MATSUMOTO, W. M. (1959) Descriptions of *Euthynnus* and *Auxis* larvae from the Pacific and Atlantic Oceans and adjacent seas. *Dana Rep.* **50**, 1–34.

MATSUMOTO, W. M. (1960) Notes on the Hawaiian frigate mackerel, genus *Auxis*. *Pacific Sci.* **14** (2), 173–177.

MEAD, G. W. (1951) Post-larval *Neothunnus macropterus*, *Auxis thazard* and *Euthynnus lineatus* from the Pacific coast of Central America. *Fish. Bull., U.S.* **52** (63), 121–127.

SCHAEFER, M. B. and MARR, J. C. (1948a) Juvenile *Euthynnus lineatus* and *Auxis thazard* from the Pacific Ocean off Central America. *Pacific Sci.* **2** (4), 262–271.

SCHAEFER, M. B. and MARR, J. C. (1948b) Spawning of yellowfin tuna (*N. macropterus*) and skipjack (*K. pelamis*) in the Pacific Ocean off Central America, with descriptions of juveniles. *Fish. Bull., U.S.*, **51** (44), 187–195.

SHIMADA, B. M. (1951a) Contributions to the biology of tunas from the western equatorial Pacific. *Fish. Bull., U.S.* **52** (62), 111–119.

SHIMADA, B. M. (1951b) Juvenile oceanic skipjack from the Phoenix Islands. *Fish. Bull., U.S.* **52** (64), 129–131.

SIEGEL, S. (1956) *Nonparametric statistics for the behavioral sciences.* McGraw-Hill, New York. 312 pp.

WADE, C. B. (1949) Notes on the Philippine frigate mackerels, family Thunnidae, genus *Auxis*. *Fish. Bull., U.S.* **51** (46), 229–240.

WADE, C. B. (1950) Juvenile forms of *Neothunnus macropterus*, *Katsuwonus pelamis*, and *Euthynnus yaito* from Phillippine seas. *Fish. Bull., U.S.* **51** (53), 409–423.

YABE, H., ANRAKU, N. and MORI, T. (1953) Scombroid youngs found in the coastal seas of Aburatsu, Kyushu in summer. *Contrib. Nankai Reg. Fish. Res. Lab.* **1** (11), 1–10.

YABE, H., UEYANAGI, S., KIKAWA, S. and WATANABE, H. (1958) Young tunas found in stomach contents. *Rep. Nankai Reg. Fish. Lab.* **8**, 31–48.

DISPLAY COPY

Made in United States of America
Reprinted from Transactions of the American Fisheries Society
Vol. 90, No. 4, October, 1961
pp. 419–423

Incidence of the Giant Trematode, *Hirudinella marina* Garcin, in Skipjack Tuna, *Euthynnus pelamis* (Linnaeus), from Marquesan and Hawaiian Waters

Eugene L. Nakamura and Heeny S. H. Yuen

Incidence of the Giant Trematode, *Hirudinella marina* Garcin, in Skipjack Tuna, *Euthynnus pelamis* (Linnaeus), from Marquesan and Hawaiian Waters[1]

EUGENE L. NAKAMURA AND HEENY S. H. YUEN

U. S. Bureau of Commercial Fisheries, Biological Laboratory
Honolulu, Hawaii

ABSTRACT

The greater incidence of the giant trematode, *Hirudinella marina* Garcin, in skipjack tuna, *Euthynnus pelamis* (Linnaeus), from Hawaii than in skipjack from the Marquesas led to the hypothesis that this difference in infestation was due to area. Comparisons with respect to sex, size, and time led to the conclusion that a major source of variation could be attributed to time. The available data did not allow a conclusion on whether or not a real difference exists between the two areas.

INTRODUCTION

During 1956 and 1957 the staff of the onolulu Biological Laboratory, U. S. Bureau f Commercial Fisheries, conducted an invesigation of the response of skipjack tuna, *uthynnus pelamis* (Linnaeus), to live bait in ie region of the Hawaiian Islands (Yuen, 959). During 1957 and 1958 a survey was iade of the "surface" tuna resources in the egion of the Marquesas Islands in northeastrn French Oceania. Studies of stomach conents of skipjack tuna were important to both f these investigations. While examining the ata, it was noticed that the incidence of the iant trematode, *Hirudinella marina* Garcin, as apparently considerably higher in skipck stomachs from Hawaii than in those from ie Marquesas. Analyses of the data, however, evealed no conclusive difference in infestaon rates between these two areas. The reilts of analyses showing differences associted with other factors such as size, sex, and me are presented below.

METHODS

Stomach samples were collected from skipack caught by the live-bait method (June, 951). The stomachs were removed intact nd placed in white muslin bags with approriate labels and then placed in 10-percent ormalin. Stomachs distended with food were lit in order to facilitate preservation. Field ata included the time and locality of capure, total length (as defined by Marr and chaefer, 1949), and the sex of the fish.

Sampling in the Marquesas was carried out from U. S. Bureau of Commercial Fisheries' research vessels. From January 1957 to November 24, 1957, samples were obtained from five females from each school fished. From November 24, 1957, to the end of the survey in the Marquesas, 10 were obtained from each school, five from females and five from males. When fewer than 10 fish were caught, samples were obtained from the entire catch. In Hawaii all of the skipjack sampling was carried out from commercial fishing vessels. During the initial phases of the study, 20 samples were taken from each school whenever possible. Later the number was reduced to 10. No attempt was made to obtain equal representation of the sexes. The Marquesan samples were obtained within a radius of 250 miles from the island of Nuku Hiva, while those from Hawaii were obtained within a radius of 150 miles from the island of Oahu.

Comparisons between infestation rates were made by chi-square tests (Snedecor, 1956). The hypothesis of no difference was rejected if the probability of chi-square was less than 0.05.

IDENTIFICATION OF TREMATODE

Representatives of the genus *Hirudinella*, digenetic trematodes belonging to the family Hemiuridae, have been reported from the stomachs of a number of scombriform fishes. Depending upon the state of contraction, they may be less than 2 and greater than 5 centimeters in length, but most of our preserved specimens were between 2 and 5 centimeters. Their life cycle is presently unknown.

The genus has been studied in detail by Nigrelli and Stunkard (1947). They ascribed the giant trematodes from the wahoo, *Acanthocybium solanderi* (Cuvier and Valenciennes), to *H. ventricosa* (Pallas). Although uncertainty was expressed about the identification of the giant trematodes found in other hosts, they considered them to belong to a single species, *H. marina* Garcin, on the basis of various morphological differences from *H. ventricosa.* The hosts of *H. marina* included the following species of scombriform fishes: *Parathunnus atlanticus* (Lesson), *Katsuwonus pelamis* (Linnaeus), *Euthynnus alletteratus* (Rafinesque), *Neothunnus macropterus* (Temminck and Schlegel), *Makaira mitsukurii* (Jordan and Snyder), *Scomberomorus maculatus* (Mitchill), and *Thunnus thynnus* (Linnaeus).

---

[1] Published by permission of the Director, U. S. ureau of Commercial Fisheries.

SINGLE AND MULTIPLE OCCURRENCES

H. marina was found in 311 of the 1,130 skipjack tuna stomachs examined. One trematode per stomach was most common. Only eight of the stomachs had more than two trematodes. The highest number found in a single stomach was four (Table 1). Although Iversen and Yoshida (1957) found as many as 17 *H. ventricosa* in a single wahoo stomach, they reported two *H. ventricosa* per stomach as the most common occurrence.

Trematodes occurred more often in skipjack stomachs collected in Hawaiian waters than in those collected in Marquesan waters (Table 1). Chi-square tests showed the differences between the two areas to be significant in the total number of stomachs infested ($\chi^2 = 26.434$; $p < 0.0001$) and also in the number of stomachs containing one trematode ($\chi^2 = 20.412$; $p < 0.0001$), but nonsignificant in the number of stomachs containing more than one.

The percentages of trematode occurrences, 20.6 percent for Marquesan skipjack and 34.3 percent for Hawaiian skipjack, are similar to those for other tunas caught in central Pacific waters. King and Ikehara (1956: page 66) found 32 percent of 166 bigeye (*Parathunnus sibi*) and 26 percent of 439 yellowfin (*Neothunnus macropterus*) with the trematodes in their stomachs. These trematodes were stated very likely to be *H. marina* by Iversen and Hoven (1958). These rates contrast sharply with the incidence of *H. ventricosa* in 98.2 percent of 220 wahoo caught in the area of the Line Islands (Iversen and Yoshida, 1957).

INCIDENCE BY SEX

The infestation rates for males and females from the two areas showed a significant difference between sexes for Marquesan skipjack tuna ($\chi^2 = 17.765$; $p < 0.0001$), but not for Hawaiian. Examination of the data indicated that this difference was probably due to the high incidence in the exclusively female samples obtained in January, February, and March of 1957. When the comparison was based on data only from those months in which both sexes were represented, the difference between sexes within the Marquesas (15.0 percent for females and 10.8 percent for males, Table 2) was not significant. Comparison within months of the infestation rates between sexes showed no significant differences in the months during which both sexes had been sampled for either Marquesan or Hawaiian skipjack.

Separation of the data into length groups from schools which had both sexes sampled (Table 2) revealed significant differences between sexes for only the 40.0–49.9-centimeter Marquesan skipjack ($\chi^2 = 4.472$; $p < 0.05$). The rest of the length groups for the Marquesan area and all for the Hawaiian area showed no significant difference between sexes.

Comparison of the incidence of trematodes in the same sex from the two areas showed significant differences. The 21 out of 195 for the Marquesan male skipjack was significantly less than the 91 out of 280 for the Hawaiian male skipjack ($\chi^2 = 29.761$; $p < 0.0001$), as was the 94 out of 363 for Marquesan female skipjack from the 92 out of 261 for Hawaiian female skipjack ($\chi^2 = 6.366$; $p < 0.02$).

While making the above comparisons, the

TABLE 1.—*Summary of single and multiple occurrences of giant trematodes in stomachs of skipjack tuna from the Marquesas and Hawaii*

[Percentage occurrences in parentheses]

Area	Number of stomachs examined	Number of stomachs containing:					Total number of stomachs containing trematodes
		0 Trematode	1 Trematode	2 Trematodes	3 Trematodes	4 Trematodes	
Marquesas	558	443 (79.4)	75 (13.4)	37 (6.6)	3 (0.5)	0 (0)	115 (20.6)
Hawaii	572	376 (65.7)	137 (24.0)	54 (9.4)	4 (0.7)	1 (0.2)	196 (34.3)

ABLE 2.—*Giant trematode incidences in stomachs of male and female skipjack tuna of various lengths from the Marquesas and Hawaii*

Item	Length group (centimeters)						Total
	30.0–39.9	40.0–49.9	50.0–59.9	60.0–69.9	70.0–79.9	80.0–89.9	
			Marquesas[1]				
ale							
Number of stomachs	—	104	55	5	29	2	195
Number with trematodes	—	5	10	1	4	1	21
Percentage infestation	—	4.8	18.2	20.0	13.8	50.0	10.8
emale							
Number of stomachs	1	124	40	6	27	2	200
Number with trematodes	0	16	9	1	4	0	30
Percentage infestation	0	12.9	22.5	16.7	14.8	0.0	15.0
oth sexes							
Number of stomachs	1	228	95	11	56	4	395
Number with trematodes	0	21	19	2	8	1	51
Percentage infestation	0	9.2	20.0	18.2	14.3	25.0	12.9
			Hawaii[2]				
ale							
Number of stomachs	1	29	31	16	159	18	254
Number with trematodes	0	4	14	9	49	6	82
Percentage infestation	0	13.8	45.2	56.2	30.8	33.3	32.3
emale							
Number of stomachs	—	25	32	20	155	5	237
Number with trematodes	—	5	13	10	56	2	86
Percentage infestation	—	20.0	40.6	50.0	36.1	40.0	36.3
oth sexes							
Number of stomachs	1	54	63	36	314	23	491
Number with trematodes	0	9	27	19	105	8	168
Percentage infestation	0	16.7	42.9	52.8	33.4	34.8	34.2

[1] Data from schools which did not have both sexes sampled are not included.

[2] Length data for 60 samples were not available. Ten of these plus 21 others had no sex data available.

agnitude of the between-year difference, parcularly of females in the Marquesas, was oticed. Since the data from the two areas did ot cover the same period of time, it was ecessary to determine whether differences xisted between years within sexes of the same rea. For the Marquesas the incidence of rematodes in females during 1957 was sigificantly greater than that in the females durng 1958 ($\chi^2 = 35.852$; $p < 0.0001$). Comarable data were unavailable for males. For awaii no yearly differences were found for emales, but for males a significant difference was found between 1956 and 1957 $\chi^2 = 7.907$; $p < 0.01$).

INCIDENCE BY SIZE

Since there was only one length group hich showed a significant difference between exes (the 40.0–49.9-centimeter group for the arquesas), the data for the two sexes were ombined for comparisons between length roups. No significant difference was oberved between sizes in the Marquesas, but a ignificant difference was observed for Hawaii $\chi^2 = 15.060$; $p < 0.005$). As seen in the data abulated in the lines labeled "Both sexes" in able 2, there was a higher incidence in the awaiian skipjack than in Marquesan skipack for each length group. Significant diferences between the same length groups from he two areas were observed for the 50.0–59.9-($\chi^2 = 9.652$; $p < 0.003$), 60.0–69.9-($\chi^2 = 4.215$; $p < 0.05$), and 70.0–79.9-($\chi^2 = 8.250$; $p < 0.005$) centimeter groups.

INCIDENCE BY SEASON AND YEAR

To make seasonal comparisons of trematode incidences, the data were divided into "season" and "off-season" (Table 3). The season months for Hawaii include May, June, July, August, and September, since the highest catch from the commercial fishery for Hawaiian skipjack occurs during these months (Yamashita, 1958). Similar seasonal catch data are not available for the Marquesan region, because a commercial fishery does not exist there. Wilson and Austin (1957), however, have reported that more than three times as many skipjack schools were sighted in the Marquesas during the southern hemisphere summer as during the southern hemisphere winter. Data for the months of November, December, January, February, and March were combined and designated as the "season" period for the Marquesan region. The remaining months were lumped together as the "off-season" for each of the areas.

No significant seasonal differences were found within the same years and same areas. When the 1957 season was compared with the 1958 season (Table 3) for the Marquesas, however, a significant difference was observed

TABLE 3.—*Seasonal and yearly variations of giant trematode incidences in stomachs of skipjack tuna from the Marquesas and Hawaii*

Item	Year			Total
	1956	1957	1958	
		Marquesas		
Season				
Number of stomachs	—	128[1]	283	411
Number with trematodes	—	57	38	95
Percentage infestation	—	44.5	13.4	23.1
Off-season				
Number of stomachs	—	15[1]	132	147
Number with trematodes	—	4	16	20
Percentage infestation	—	26.7	12.1	13.6
		Hawaii		
Season				
Number of stomachs	383	129	—	512
Number with trematodes	117	57	—	174
Percentage infestation	30.5	44.2	—	34.0
Off-season				
Number of stomachs	40	20	—	60
Number with trematodes	16	6	—	22
Percentage infestation	40.0	30.0	—	36.7

[1] These samples were from female skipjack only.

($\chi^2 = 47.708$; $p < 0.0001$), as was the case for the Hawaiian area when the 1956 season was compared with the 1957 season ($\chi^2 = 7.808$; $p < 0.01$). Differences between the off-seasons of 1957 and 1958 for the Marquesas and of 1956 and 1957 for Hawaii were not significant. For the Marquesas data, it is possible that the difference between seasons may have been influenced by the nonrepresentation of males in the 1957 samples. Accordingly, the 1958 data for male skipjack were eliminated. The season difference for 1957 and 1958 was still significant ($\chi^2 = 26.895$; $p < 0.0001$). The off-season difference was not. Comparison of season ($\chi^2 = 12.598$; $p < 0.0005$) and off-season ($\chi^2 = 13.923$; $p < 0.0003$) totals showed that the trematode incidences in Hawaiian skipjack were significantly higher than in Marquesan skipjack. When the data were rearranged and examined for differences between years within the same length group and within the same area, significant differences were found in three length groups from the Marquesas: 40.0–49.9-centimeter ($\chi^2 = 13.494$; $p < 0.0003$), 50.0–59.9-centimeter ($\chi^2 = 4.334$; $p < 0.05$), and 60.0–69.9-centimeter ($\chi^2 = 9.892$; $p < 0.003$). For the area of Hawaii, only one length group, 60.0–69.9-centimeter ($\chi^2 = 5.730$; $p < 0.03$), showed a significant yearly difference.

The results to this point led to a final comparison, a between-area, within-year comparison, for which only the 1957 data could be used. The difference was not significant.

DISCUSSION AND CONCLUSION

The contrast in the trematode incidences between Hawaiian skipjack tuna and Marquesan skipjack tuna led to the hypothesis that this difference was due to area. Significant differences revealed by the following comparisons supported the hypothesis: males and females from the Marquesas versus those from Hawaii, length groups from the Marquesas versus corresponding length groups from Hawaii (for the 50-, 60-, and 70-centimeter groups), and seasons and off-seasons in the Marquesas versus those in Hawaii.

Within area comparisons of the following categories, however, also yielded significant differences: females of different years in the Marquesas, males of different years in Hawaii, seasons of different years of both areas, length groups in Hawaii, and within certain length groups of different years (the 40-, 50-, 60-centimeter groups of the Marquesas and the 60-centimeter group of Hawaii). All of the differences within area are associated with time and size. Since size itself is associated with time, it appears that a major source of variation may be attributed to time. That time was a more important factor in the observed differences is supported by the data of 1957, the only year common to both areas. The difference between the two areas was not significant for that year. Regrettably, the data from the two areas, collected incidentally to other studies, do not cover the same years. Thus, they do not permit a measure of the time variable in those comparisons which show an inter-area difference.

In conclusion, the difference observed between the incidences of *Hirudinella marina* in skipjack tuna from Hawaii and from the Marquesas seems to be associated with time rather than area. Whether or not a real difference does exist between these areas could not be determined from the available data.

LITERATURE CITED

IVERSEN, EDWIN S., AND EARL HOVEN. 1958. Some trematodes of fishes from the central equatorial Pacific. Pacific Science, 12(2): 131–134.

IVERSEN, EDWIN S., AND HOWARD O. YOSHIDA. 1957. Notes on the biology of the wahoo in the Line Islands. Pacific Science, 11(4): 370–379.

JUNE, FRED C. 1951. Preliminary fisheries survey of the Hawaiian-Line Islands area. Part 3—The live-bait skipjack fishery in the Hawaiian Islands. Commercial Fish. Rev., 13(2): 1–18.

KING, JOSEPH E., AND ISAAC I. IKEHARA. 1956. Comparative study of food of bigeye and yellowfin tuna in the central Pacific. Fish. Bull., U. S. Fish and Wildl. Serv., 57: 61–85.

ARR, JOHN C., AND MILNER B. SCHAEFER. 1949. Definitions of body dimensions used in describing tunas. Fish. Bull., U. S. Fish and Wildl. Serv., 51: 241–244.

IGRELLI, ROSS F., AND HORACE W. STUNKARD. 1947. Studies on the genus *Hirudinella*, giant trematode of scombriform fishes. Zoologica, 31(13): 185–196.

NEDECOR, GEORGE W. 1956. Statistical methods. 5th ed. Iowa State College Press, Ames, Iowa. 534 pp.

WILSON, ROBERT C., AND THOMAS S. AUSTIN. 1957. U. S. Fish and Wildlife Service task force in the Marquesas. Pan American Fisherman, 11(12): 6–7.

YAMASHITA, DANIEL T. 1958. Analysis of catch statistics of the Hawaiian skipjack fishery. Fish. Bull., U. S. Fish and Wildl. Serv., 58: 253–278.

YUEN, HEENY S. H. 1959. Variability of skipjack response to live bait. Fish. Bull., U. S. Fish and Wildl. Serv., 60: 147–160.

R. H. RIFFENBURGH

A SYSTEM ANALYSIS OF THE MARINE ECOLOGY

Reprinted from the
Bulletin of the International Statistical Institute
VOL. XXXVIII: PART III
TOKYO 1961

A SYSTEM ANALYSIS OF THE MARINE ECOLOGY

by

ROBERT H. RIFFENBURGH*
Mathematical Statistician
U.S. Bureau of Commercial Fisheries
Honolulu Biological Laboratory, Honolulu, Hawaii

Introduction

An ecological problem in fisheries research is that of describing explicitly the complicated interrelationships among population size, recruitment, natural mortality, fishing mortality, and predation habits among several species at each of several trophic levels. Although several individuals have studied population dynamics (cf. 1, 2, 4, 5), the usual approach has been to consider a single species exclusive of its interaction with other species. In this paper, an attempt is made to study the entire system.

In order to speak in general, let us consider r trophic levels with s_i species in the i-th trophic level. Thus, a variable x_{ij} refers to the measure of the variable x associated with the j-th species in the i-th trophic level; $j=1, 2, \cdots, s_i$; $i=1, 2, \cdots, r$. It is recognized that this classification system is somewhat arbitrary. In general the successive trophic levels are occupied by plants, herbivores, and carnivors, with whatever sub-classifications are necessary for the study of species of particular interest. The number of trophic levels and sub-levels in such a classification might be in the neighborhood of six. The species within each trophic level may be classified according to similarity of eating habits, i. e. those which feed on essentially the same prey would be classified together. The number of species within each trophic level in such a classification might be in the neighborhood of three or four.

In addition to this general problem of describing an entire system, there is a second problem of predicting the effects of external phenomena upon the equilibrium of the system, and perhaps predicting future balances that occur after an external phenomenon has effected an imbalance. By external phenomena I refer to such things as fishing mortality, which constitutes a loss from the system, or epidemics which produce large effects but occur so infrequently as to not constitute a regular part of the system. I hope here to contribute to the solution of both problems.

The fundamental part of the analysis depends upon measuring the mass and/or energy flux from each classification to each other classification The parameters involved must be estimated by a set of simultaneous equations derived from known biological relationships. Two cases will be treated :

---

* Also on the Mathematics Faculty, University ot Hawaii, Honolulu.

Case I: the system is in equilibrium
Case II: the system is not in equilibrium.

For the first case, recruitment equals mortality in all classifications, so that only the mortality need be considered; the size (in weight) of the populations are constant. For the second case, recruitment does not equal mortality in all classifications and the sizes of the populations must be considered. Various amounts of matter will be postulated as being removed from the system by fishing or other causes and the pattern of probable results will be predicted by the use of Markov chains.

A cross classification of analysis is the consideration of the system based upon the variables:

Case A: the weight of animals (or plants)
Case B: a measure of transmitted energy.

Both have some disadvantages and each provides information not obtainable from the other.

Solutions: Case A-I

The basis on which the complete analysis is constructed assumes the knowledge of parameters π_{ijkl}=the probability that the weight of a random member of the j-th species of the i-th trophic level will be consumed in the given time interval (say a year) by a random member of the l-th species of the k-th trophic level; $i, k=1, 2,\ldots r$; $j=1, 2, \cdots, s_i$; $l=1, 2,\ldots, s_k$. To standardize such animal weights, a basic unit of "one pound" will be used. At the present time, such parameters are unknown and unestimated; they are unlikely ever to be known exactly. Methods of estimating such parameters are considered in the last section. For the present let us assume that p_{ijkl}, estimates of π_{ijkl}, are available.

For case A-I, the system is in equilibrium so that the weight of animals present in any one year is the same as the weight in any ensuing year.

Let us define a square matrix P, with dimensions $\sum_{i=1}^{r} s_i+1$, whose typical ik-th partition is P_{ik}, a sub-matrix with dimensions $s_i \times s_k$, whose typical element is p_{ijkl}. After the $\sum_{i=1}^{r} s_i$ rows and columns, there is an additional row and column. This last row is the vector

$$[0 \quad 0 \quad 0 \cdots 0 \quad 1]$$

and the last column is composed of elements p_{ijf}, the probability that a pound of the j-th species of the i-th trophic level exits from the system, not to return. "Exit" will here mean that the pound is removed by fishing, but it could as well imply death by disease, radiation, or any other cause except predation. In order to have P a probability matrix, we must have the restriction:

$$\sum_{k=1}^{r} \sum_{l=1}^{s_k} p_{ijkl}+p_{ijf}=1. \tag{1}$$

Such a restriction is both reasonable and essential from a biological view. The probability p_{ijij} is the probability that the pound stays in its own species (either by remaining untouched or by cannibalism), p_{ijf} is the probability that the pound exits from the system, and all other p's are probabilities that the pound passes from one position in the system to another; thus all possibilities are accounted for and the sum of probabilities over the entire possibility space must equal unity.

P appears as follows:

$$\begin{bmatrix} p_{1111} & p_{1112} & \cdots & p_{111s_1} & p_{1121} & \cdots & p_{11rs_r} & p_{11f} \\ p_{1211} & p_{1212} & \cdots & p_{121s_1} & p_{1221} & \cdots & p_{12rs_r} & p_{12f} \\ \vdots & \vdots & & \vdots & \vdots & & \vdots & \vdots \\ p_{1s_111} & p_{1s_112} & \cdots & p_{1s_11s_1} & p_{1s_121} & \cdots & p_{1s_1rs_r} & p_{1s_1f} \\ p_{2111} & p_{2112} & \cdots & p_{211s_1} & p_{2121} & \cdots & p_{21rs_r} & p_{21f} \\ \vdots & \vdots & & \vdots & \vdots & & \vdots & \vdots \\ p_{rs_r11} & p_{rs_r12} & \cdots & p_{rs_r1s_1} & p_{rs_r21} & \cdots & p_{rs_rrs_r} & p_{rs_rf} \\ 0 & 0 & \cdots & 0 & 0 & \cdots & 0 & 1 \end{bmatrix} \tag{2}$$

Let us define by N the $1\times\left(\sum_{i=1}^{r} s_i+1\right)$ vector of n_{ij}, the number of pounds of the j-th species of the i-th trophic level entering the system for disposition during this time period. Of course the last element is zero, since no life which has left the system may reenter.

There are two types of quantities which are of particular interest: the size of the j-th species at the end of the time period and the total catch (or total pounds lost from the system). The vector NP would give these quantities if the animals were physiologically 100% efficient, i. e. if a pound eaten provided a pound of growth. Since the organisms are not 100% efficient, there results another source of loss of weight from the system in the form of waste products, etc. To account for this loss from the system, the probabilities in P should be weighted. This can be most easily effected by redefining the p_{ijkl} as the probability that a pound from species j of trophic level i will be consumed and fully utilized in growth by a member of species l of trophic level k. To conform to the restriction that the sum of elements of any row be unity, another row and column must be added to P, such that the bottom row vector is

$$[0 \quad 0 \cdots 0 \quad 0 \cdots 0 \quad 0 \quad 1]$$

and the last column vector is the transpose of

$$[p_{11x} \quad p_{12x} \quad \cdots \quad p_{1s_1x} \quad p_{21x} \quad \cdots \quad p_{rs_rx} \quad 0 \quad 1],$$

where

$$p_{ijx}=1-\sum_{k=1}^{r}\sum_{l=1}^{s_k} p_{ijkl}-p_{ijf}.$$

This p_{ijx} represents a second loss to the system, but one which is not utilized by man. The vector N adds one element, a zero, to have dimensions $1\times\left(\sum_{l=1}^{r} s_r+2\right)$, and appears as:

$$N=[n_{11} \quad n_{12} \quad \cdots \quad n_{1s_1} \quad n_{21} \quad \cdots \quad n_{rs_r} \quad 0 \quad 0]. \tag{3}$$

For case A-I in which equilibrium is assumed, the vector N is the set of weights entering the system each time period regardless of losses. Since the weight of a species remaining from the last time period plus this time period's recruitment equals the weight of the species entering this time period, $NP+R=N$ for case A-I, where R is a vector of recruitment quantities.

It should be observed that for case A, P is a patterned matrix in which the greatest number of partitions are null. If P be partitioned into a matrix in which the ik-th partition P_{ik} is the sub-matrix composed of the probabilities that the weight of the i-th trophic level goes to the k-th trophic level, then, assuming the weight of any trophic level is passed on only to the next higher level, P would appear as

$$\text{(4)} \qquad \begin{bmatrix} \delta_{jl}p_{1j1l} & P_{12} & O & \cdots & O & P_{1f} & P_{1x} \\ O & \delta_{jl}p_{2j2l} & P_{23} & \cdots & O & P_{2f} & P_{2x} \\ O & O & \delta_{jl}p_{3j3l} & \cdots & O & P_{3f} & P_{3x} \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ O & O & O & \cdots & \delta_{jl}p_{s_rjs_rl} & P_{s_rf} & P_{s_rx} \\ O & O & O & \cdots & O & 1 & 0 \\ O & O & O & \cdots & O & 0 & 1 \end{bmatrix}$$

where δ_{jl} is Kronecker's delta. It is obvious that any power of P will be triangular.

One possible application of the analysis thus far presented is the concept of increasing the commercial catch of a particular species or a set of species by exerting fishing pressures in some optimum pattern. Since fishing effort is independent of predation effort (i. e. in the sense that predation effort is fixed in advance of fishing effort, at least for small intervals of time, and the fishing effort is arbitrary to man), and by the restriction of rows summing to unity, a change (increment or decrement) of d_{ij} in p_{ijf} evokes a change in p_{ijkl} of

$$\text{(5)} \qquad d_{ijkl} = -\frac{d_{ij}\,p_{ijkl}}{\sum\limits_{k}\sum\limits_{l} p_{ijkl}+p_{ijx}}, \qquad d_{ijx} = -\frac{d_{ij}\,p_{ijx}}{\sum\limits_{k}\sum\limits_{l} p_{ijkl}+p_{ijx}}$$

Then the typical ij-th row of P becomes the vector

$$\text{(6)} \qquad [(p_{ij11}+d_{ij11})\cdots(p_{ijrs_r}+d_{ijrs_r})(p_{ijf}+d_{ij})(p_{ijx}+d_{ijx})].$$

The problem now is to choose the d_{ij} such that either the element of NP associated with the total catch per time period or the element $n_{ij}(p_{ijf}+d_{ij})$ for some ij is maximized. The solution for the latter in this case of equilibrium is trivial and ridiculous: increase d_{ij} until $p_{ijf}+d_{ij}=1$, in which case all fish of that species in the ocean are caught, but by the equilibrium restriction the number entering the next time period will be unaffected by the catch, which obviously does not conform to reality. It is apparent that this problem can be more profitably considered in case A-II.

Solutions: Case A-II

The situation in this case is much the same mathematically as in the preceding section, but with alterations as follows. With the restriction of equilibrium dropped, the vector R of recruitment quantities is not specified by N and P, and so must be considered independently.

Recruitment is variously thought by biologists to be related to population size and to be unrelated to population size. Since one female may produce very large numbers of eggs, the pertinent influences on number of larvae surviving to adulthood seem to be food availability and intensity of predation upon such larvae rather than the initial number hatched. I shall take this view, at least when extremely large population changes are not present, so that R is a vector of random variables independent of N (for large N). R may be written as $R=E(R)+\underset{\sim}{e}$, where $\underset{\sim}{e}$ is a vector of random deviations with zero expectation. Since we are considering essentially a "typical" system interrelationship rather than possible extremes of relationship, we shall take the vector of recruitment each time period to be $E(R)=\dot{R}$.

Taking N as in (3), P as in (4), we have the weight in the various populations at the end of the time period as:

$$N^{(1)}=NP+\dot{R}. \tag{7}$$

In case II, the weight of animals (or plants) entering any given time period is not restricted to be the same as for any other time period, so that it becomes of interest to follow the weight vector through successive time periods. Let us denote by $N^{(n)}$ the weight vector of populations at the end of the n-th time period (i. e. entering the $(n+1)$-th time period). By the usual theory of Markov chains we find

$$N^{(n)}=NP^n+\dot{R}\sum_{h=1}^{n} P^{h-1}\ , \tag{8}$$

where $P^0\equiv \mathrm{I}$.

To pursue our example of choosing fishing efforts such as to maximize the sum of catches over many years, let us again cause a vector $\varDelta$ of changes d_{ij} as defined in (5) to be effected on the vector of catch probabilities (by changing fishing effort) so that the typical row of P will appear as in (6). The desired solution is obtained by finding $\varDelta$ to maximize one (or a set of) catch weight(s) summed over a desired number of time periods, i. e. maximize $\sum_{h=1}^{n} n_{ij}{}^{(h)}\, p_{ijf}+d_{ij}$, where $n_{ij}{}^{(h)}$ is the ij-th element of $N^{(h)}$ and the ij-th species is the species of commercial interest. Here n is a finite integer>0.

Let us now consider the ultimate result of the ecological system as defined. As n becomes large, $N^{(n)}$ approaches an ultimate disposition of weights.

$$N^*=\lim_{n\to\infty} N^{(n)}=N\lim_{n\to\infty} P^n+\dot{R}\lim_{n\to\infty}\sum_{h=1}^{n} P^{h-1}. \tag{9}$$

Since P possesses two absorbing states, $\lim_{n\to\infty} P^n$ will go to the form

$$\left[\begin{array}{c|c} O & A \\ \hline O & I \end{array}\right],$$

where A is a $\left(\sum_{i=1}^{r} s_i\times 2\right)$ matrix, the elements of whose rows sum to unity.

However, $\lim_{n\to\infty}\sum_{h=1}^{n} P^{h-1}$ contains P and $\dot{R}P$ has no null elements, which implies that N^* contains no null elements. This implies biologically that so long as an assumption of R with all non-null elements holds, the system will not disintegrate and no species will become extinct.

Implicit in the Markov chain is the assumption of fixed P. This assumption is reasonable for a steady state system which has been observed in isolated cases, but it is obvious that a marked change in relative density of two competing predators will alter the proportion of a prey species being consumed by each, and hence alter elements of P. Thus a more general analysis and prediction will be obtained if we define P_h as a P derived anew at the end of the h-th time period by the methods in the last section, whence (8) alters to

$$N^{(n)} = NP\prod_{h=1}^{n-1} P_h + \dot{R}\left(\sum_{f=1}^{n-1}\prod_{h=f}^{n-1} P_h + I\right) \tag{10}$$

Once a change is effected, and for $N^{(n)}$ as defined in (10), if there exists a positive integer ν such that $|N^{(n+1)} - N^{(n)}| \leq \varepsilon$ for every $n > \nu$, ε an arbitrarily small non-negative quantity, then the system is said to be able to return to equilibrium, and $N^{(n)}$ and P_n define to any desired degree of approximation the new equilibrium.

Solutions: Cases B-I, B-II

In case B, the unit transmitted from one species to another is not the weight of animals, but a more basic measure of energy (and/or matter). In this case, all organic matter may be considered. The diseased fish feeds his parasites and thus is not lost from the system. A fish eats, and produces waste products, which are acted upon by bacteria and are subsequently available as plant nutrients. In a complete analysis of this type, the path of *all* energy transfer is traced so that (except for removal by man) no energy is lost from the system. Heat loss is replaced by sunlight. River discharges are added to the system. Thus, a much more complete analysis is permissible, although the estimation of the probabilities involved will be much more difficult and likely less exact, which will limit the usefulness of this case. In a recent paper, Odum(3) discusses some of the variables involved in case B-I, but no attempt at a numerical analysis of the system or a predictive model was made, nor were feedbacks to one part from changes elsewhere in the system included.

Mathematically, P is defined as in (2), since the p_{ijx} are no longer necessary. Furthermore, any species may make a contribution of one sort or another to any other species, so that powers of P are not necessarily triangular.

Derivation of the matrix P

Estimators for the elements of P will be derived for case A. Estimators for case B are similar mathematically, but depend on more complex physiological measurement, which is not currently feasible.

Assumption 1. Foraging effort e_{ij} of species ij (or, more generally, the volume of water exposed to the predator) is a function of the density of predator ij.

Assumption 1 a. e_{ij} is approximately linear with n_{ij} with boundary condition (0, 0) and slope m_{1ij}, i.e. $e_{ij} \doteq m_{1ij}n_{ij}$.

Assumption 1 will be considered to be self-obvious; Assumption 1a should be justified. Consider separately predation by non-schooled and schooled animals. If the animals are randomly placed and non-schooled, and the measure of density is the continuous variate weight, then the volume of water exposed to a fixed number n_{ij} of species ij as the animals grow in weight will be constant or increasing linearly with a very small slope as the animals are non-self-mobile or self-mobile respectively. When an additional member of the species is recruited, the function e_{ij} takes a sudden increase or step. A line constructed through the steps represents the average function e_{ij} on n_{ij}, which illustrates that the scouting effort is approximately linear with the weight of individuals. The deviations from this line are very small. The slope m_{1ij} will be determined by the scale on the e_{ij}-axis. If the animals are schooled, the situation is precisely the same, except that the step represents the addition of a school rather than a single individual. The magnitude of the increment or step will be greater in each instance, but is still quite small relative to the weight of animals in the ocean.

Assumption 2. The weight of prey $i-1$, l consumed by ij, $n_{(i-1)le_{ij}}$, increases linearly with scouting effort, e_{ij}, with boundary condition (0, 0) for fixed prey density.

Then since a linear function of a linear function is linear,

$$n_{(i-1)le_{ij}} = m_{2ij}n_{ij}, \tag{11}$$

for fixed density of prey species $i-1$, l.

By analogous reasoning, if the prey density $n_{(i-1)l}$ of species $i-1$, l of predation interest to species ij is allowed to vary and n_{ij} is held fixed, we may arrive at

Assumption 3. The weight of prey $i-1$, l consumed by ij, $n_{(i-1)le_{ij}}$, increases linearly with an increase in density of $i-1$, l, $n_{(i-1)l}$, with boundary condition (0, 0) for fixed density of predator and fixed scouting effort.

Then

$$n_{(i-1)le_{ij}} = m_{3(i-1)l}n_{(i-1)l}, \tag{12}$$

for fixed n_{ij}.

Now if both n_{ij} and $n_{(i-1)l}$ are allowed to vary,

$$n_{(i-1)le_{ij}} = f(n_{ij},\ n_{(i-1)l}),$$

where $f_1(n_{ij}\,|\,n_{(i-1)l}) = m_{2ij}\,n_{ij}$ and $f_2(n_{(i-1)l}\,|\,n_{ij}) = m_{3(i-1)l}n_{(i-1)l}$.

Then since

$$f(n_{ij},\ n_{(i-1)l}) = f_3(n_{ij})f_2(n_{(i-1)l}\,|\,n_{ij}) = f_4(n_{(i-1)l})f_1(n_{ij}\,|\,n_{(i-1)l}),$$

we substitute to obtain

$$m_{3(i-1)l}n_{(i-1)l}f_3(n_{ij}) = m_{2ij}n_{ij}f_4(n_{(i-1)l}),$$

from which

$$f_3(n_{ij}) \propto n_{ij} \quad \text{and} \quad f_4(n_{(i-1)l}) \propto n_{(i-1)l}.$$

Then

$$n_{(i-1)le_{ij}} = f(n_{ij},\ n_{(i-1)l}) \propto n_{ij}n_{(i-1)l} = b_{(i-1)lij}n_{ij}n_{(i-1)l} \tag{13}$$

where $b_{(i-1)lij}$ is an arbitrary scale parameter.

Denote by μ_{ij} an estimate of the mortality rate per time period of species ij (excluding cannibalism). Suppose these quantities are available (estimation techniques are largely biological and will not be discussed here). Denote by y_{ij} an estimate of the average diet in weight of species ij. These diets are estimable from growth curves of species plus knowledge of their physiological efficiencies. Also the p_{ijx} can be found physiologically, which will permit estimation of p_{ijkl} when n_{ij} and n_{ijekl} are found. Denote by v_{ijkl} an estimate of the proportion of diet of kl represented by ij. These diet quantities are estimable by stomach content analysis of kl or similar biological techniques. Denote by c_{ij} the catch or its estimate of ij per time period, which is a matter of record. Then the following equations emerge :

$$\mu_{(i-j)l} n_{(i-1)l} - \sum_{j=i}^{si} n_{(i-1)le_{ij}} - c_{(i-1)l} = 0 \tag{14}$$

$$(1-\mu_{(i-1)l}) = p_{(i-1)l(i-1)l} \tag{15}$$

$$n_{ij} v_{(i-1)lij} y_{ij} = n_{(i-1)le_{ij}} \tag{16}$$

$$\sum_{i=1}^{r} \sum_{j=1}^{si} n_{(i-1)le_{ij}} + (1-y_{(i-1)l}) n_{(i-1)l} = n_{(i-1)l} \tag{17}$$

$$b_{(i-1)lij} = n_{(i-1)l}^{-1} n_{ij}^{-1} n_{(i-1)le_{ij}} \tag{18}$$

$$p_{(i-1)lij} = n_{(i-1)l}^{-1} n_{(i-1)le_{ij}} (1-p_{ijx}) \tag{19}$$

$$p_{(i-1)lf} = n_{(i-1)l}^{-1} c_{(i-1)l}. \tag{20}$$

Solving this set of equations, we now have the matrix P in addition to estimates of the total weight of animals of the various species.

Summary

An ecological problem in fisheries research is that of describing explicitly the complicated interelationships among population size, recruitment, mortality, predation habits, and fishing effort among the several species at each of several trophic levels. A second problem is that of predicting the effects of varied fishing efforts, epidemics and other external phenomena upon the equilibrium of the system, and predicting future balances that occur after an external phenomenon has effected an imbalance. This paper is a first effort at providing a solution to both problems.

The fundamental part of the analysis depends upon measuring the amount of each classification contributed to each other classification as nutrient, and is in some ways similar mathematically to Leontief's economic input-output analysis. The parameters to be utilized must be estimated by a set of simultaneous equations derived from known biological relationships. Two cases are treated : the system is in equilibrium ; the system is not in equilibrium. For the first case recruitment equals mortality in all classifications, so that only the mortality is analyzed : the size of the population is static. For the second case, the entire population must be considered, and additional classifications, e. g. the animals left alive, the amount of recruitment, etc., are added. The additional classifications cause mathematical problems, which are discussed.

A cross-classification of analysis is the consideation of the system based upon a variable : the weight of animals or plants ; and based upon a variable : a measure of transmitted energy. Both have some disadvantages and each provides information not obtainable from the other. Both are presented and discussed.

In order to consider the second problem, i.e. prediction of change in the sys-

tem, various amounts of animals are postulated as being removed from the system due to fishing effort or other causes, and the pattern of probable results is predicted by the use of a modified Markov chain, along with expected results. The essential problem mathematically is that the stochastic matrix must be redefined after each time period in order to admit a feedback effect.

References

[1] Beverton, R. J. H. and Holt, S. J. (1957) : On the dynamics of exploited fish populations, *Fishery Investigations, 19,* Series II, 1–533.

[2] DeLury, D. B. (1947) : On the estimation of biological populations, *Biometrics, 3,* No. 4, 145–167.

[3] Odum, H. T. (1960) : Ecological potential and analogue circuits for the ecosystem, *American Scientist, 48,* No. 1, 1–8.

[4] Ricker, W. E. (1958) : Handbook of computations for biological statistics of fish populations, *Bulletin No. 119, Fisheries Research Board of Canada,* 1–300.

[5] Schaefer, M.B. (1954) : Some aspects of the dynamics of populations important to the management of the commercial marine fisheries, *Inter-American Tropical Tuna Commission, 1,* No. 2, 27–56.

RÉSUMÉ

Un problème écologique dans les recherches de pêche est celui de décrire explicitement les relations compliquées entre la grandeur de la population, le recrutement, la mortalité, les habitudes de prédation, et l'effort de pêche relatif aux différentes especes à chacun de plusieurs niveaux trophiques. Un second problème est celui de prédire les effets de différents efforts de pêche, des épidémies, et d'autres phénomènes externes sur l'équilibre du système, et aussi de prédire les équilibres futurs qui apparaîtront depuis qu'un phénomène externe aura effectué un deséquilibre. Le présent article est un premier essai de fournir une solution a ces deux problèmes.

La partie fondamentale de l'analyse dépend de la mesure de la proportion de chaque classe fournie a chacune d'autres classes comme nourriture; et c'est en quelques points mathématiquement similaire à l'analyse économique de l'"input-output" de Leontief. Les paramétres á utiliser doivent etre estimés par un système d'équations simultanées derivés de relations biologiques connues. Ici deux cas sont étudies: le système est en équilibre; le système n'est pas en équilibre. Pour le premier cas, le recrutement est égal à la mortalité dans toutes les classes, de manière que seule la mortalité est analysée: le grandeur de la population est statique. Pour le second cas il faut considérer la population entière, et des classes additionelles (par exemple les animaux qui restent vivants, le quantité de recrutement, etc.) qui y sont ajoutées. Ces classes additionelles posent des problèmes mathématiques, lesquels sont discutés.

Une contre-classification de l'analyse consiste en un traitement du système basé sur une des variables: le poids des animaux ou des plantes; ou la quantité d'énergie transmise. Tous les deux ont des désavantages et chacun des deux fournit des renseignements que l'on ne peut pas obtenir de l'autre. Tous les deux sont présentés ici et le premier est discuté.

Pour considérer le second problème, celui de prédire des changements dans le système, on suppose la soustraction de differentes quantités d'animaux du système

due aux efforts de pêche ou à d'autres causes, et on prédit la suite des résultats probables en utilisant une chaîne de Markov modifiée. Mathématiquement le problème essentiel est celui de redéfinir la matrice stochastique apres chaque période de temps afin qu'il soit tenu compte l'effet régénérateur.

DISPLAY COPY

printed from COPEIA, 1961, No. 4, pp. 467-470, December 19
nted in U. S. A.

OCCURRENCE OF EARLY DEVELOP- ENTAL STAGES OF THE OBLONG OCEAN NFISH *RANZANIA LAEVIS* (PENNANT) THE CENTRAL NORTH PACIFIC.—Little s been reported concerning the morphology d distribution of the early developmental ges of the oblong ocean sunfish, *Ranzania vis* (Pennant), in the central North Pacific. e only previous report is that of Jordan and yder (1901, *Proc. U. S. Nat. Mus. 24(1254):263*), o mention a 4-inch specimen (referred to as *makua*) collected at Honolulu but offer no ditional information. Mention of adult oblong ean sunfish occurrences in the central North cific, usually of single specimens collected om the immediate vicinity of Honolulu, are ore numerous: Jenkins (1895, *Proc. Calif. Acad. . 5:779–84*), reported a new species, *R. makua* nkins, collected from the vicinity of Pearl arbor, Oahu; Fowler (1900, *Proc. Acad. Nat. . Phila:514*), described a skin of *R. makua* llected by J. K. Townsend in Honolulu in 35; Jordan and Evermann (1903, *Bull. U. S. sh Comm. 23:440*), provided a redescription of e type specimen, *R. makua*; Gunther (1910, *J. us. Godeffroy 9(17):477*), reported a specimen *R. truncata* collected from the Hawaiian Islands; Jordan and Jordan (1922, *Mem. Carnegie us. 10(1):89*), mention four *R. makua* collected om Honolulu; Fowler (1922, *Copeia 112:84*), ted *R. truncata* as present in the fish collection the *Acad. Nat. Sci. Phila.*; Jordan, Evermann d Tanaka (1927, *Proc. Calif. Acad. Sci. 16(4): 0*), include *R. makua* in a list of fishes colcted from the Hawaiian Islands; Fowler (1928, *em. Bishop Mus. 10:475*), reported the collecon of single specimens of *R. truncata* on several casions at Honolulu and later (1938, *Acad. at. Sci. Phila. Mon.*) included *R. truncata* in a st of fishes collected from Eastern Oceania.

This report is concerned with the morphology and distribution of early developmental stages of *R. laevis* from plankton samples in the collections of the Bureau of Commercial Fisheries Biological Laboratory, Honolulu, Hawaii (HBL).

A total of 1,531 identifiable young stages of *R. laevis* were separated from 98 plankton samples, of which 28 contained specimens, (Table 1). These plankton samples had been collected during 1959 as part of an oceanographic survey of Hawaiian waters, extending from 13° to 26°N. latitude and from 145° to 170° W. longitude (Fig. 1). All hauls were of 30 minutes duration and were taken at approximately 2100 hours using a 1-m net (aperture widths: belly section, 0.65 mm; rear section 0.3 mm) towed obliquely from 60 m to the surface, with the exception of two oblique tows from 140 m. An additional 1,084 *R. laevis* larvae were separated from plankton samples collected from an International Geophysical Year monitoring station located at 21°10′N. latitude, 158°19′W. longitude. The station was occupied at monthly intervals from July to December 1958 by HBL personnel. When conditions permitted, two evening and two daylight oblique tows from 60 m to the surface were taken with a 1-m net (aperture widths same as above). Of a total of 64 samples collected, only

TABLE 1. SEASONAL OCCURRENCE OF *Ranzania laevis* COLLECTED IN 1959 ON OCEANOGRAPHIC SURVEYS, 13° TO 26°N., 145° TO 170°W.

	Jan.–Feb.	March–April	May	July	Oct.
Number of plankton hauls	31	21	22	13	11
Number of hauls containing *R. laevis*	13	12	3	—	—
Total number of *R. laevis*	852	671	8	—	—

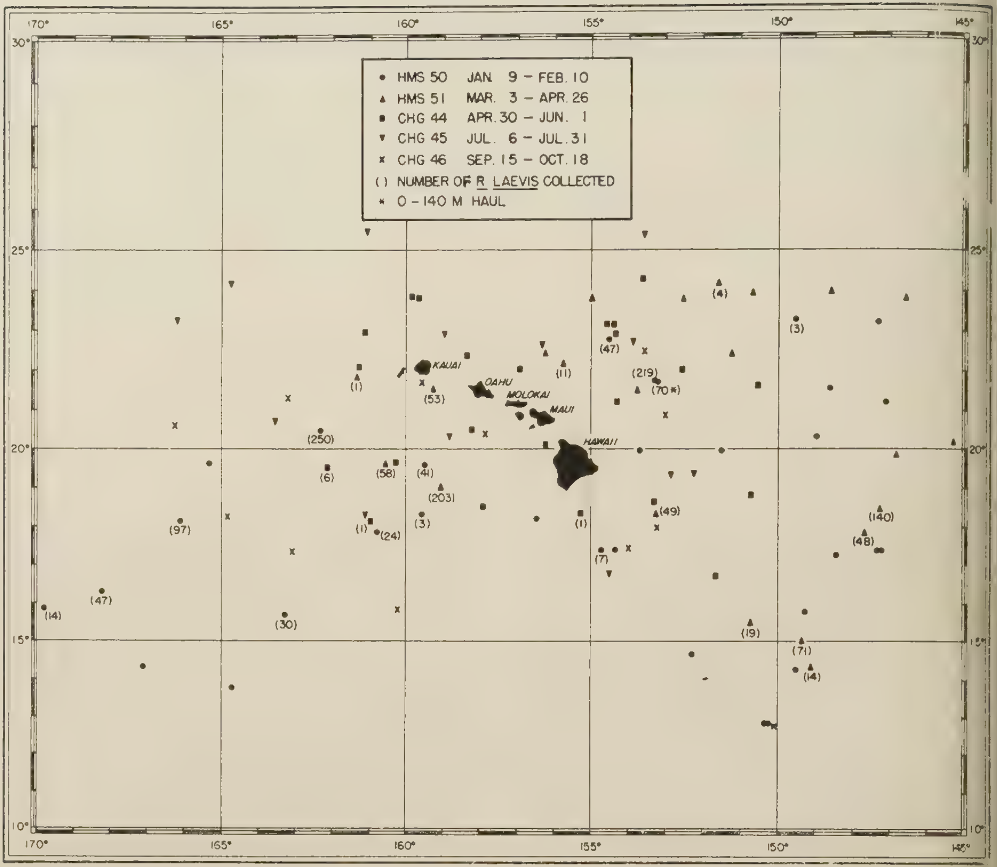

● HMS 50 JAN. 9 – FEB. 10
▲ HMS 51 MAR. 3 – APR. 26
■ CHG 44 APR. 30 – JUN. 1
▼ CHG 45 JUL. 6 – JUL. 31
× CHG 46 SEP. 15 – OCT. 18
( ) NUMBER OF R. LAEVIS COLLECTED
* 0 – 140 M HAUL
170°
165°
160°
155°
150°
145°
30°
25°
20°
15°
10°
KAUAI
OAHU
MOLOKAI
MAUI
HAWAII
(4)
(3)
(47)
(219)
(70*)
(11)
(1)
(53)
(250)
(6)
(58)
(41)
(203)
(3)
(1)
(24)
(97)
(1)
(7)
(49)
(140)
(48)
(14)
(47)
(30)
(19)
(71)
(14)

Fig. 1. Cruise periods, vessel positions during plankton hauls, and positions of larval occurrence of *Ranzania laevis*. HMS = *Hugh M. Smith*, CHG = *Charles H. Gilbert*.

Table 2. Seasonal and Day-Night Variation in Numbers of *R. laevis* Collected in 1957–58 from the IGY Plankton Station, 21°10′N., 158°19′W.

Date	Number of daylight tows	Number of *R. laevis*	Number of night tows	Number of *R. laevis*	Vessel and cruise
7/21/57	1	—	1	—	Charles H. Gilbert—34
8/20/57	1	—	2	—	" " " "
9/16/57	2	—	2	—	Hugh M. Smith—41
10/29/57	2	—	2	—	" " " "
11/26/57	2	—	2	—	" " " —42
12/19/57	2	—	2	—	Charles H. Gilbert—36
1/21/58	2	759	2	252	" " " —37
2/27/58	2	65	2	8	Hugh M. Smith—43
3/24/58	2	—	2	—	" " " —44
4/21/58	1	—	2	—	Makua—13
5/30/58	2	—	—	—	Charles H. Gilbert—39
6/21/58	2	—	2	—	" " " "
7/21/58	—	—	2	—	Hugh M. Smith—46
8/19/58	2	—	2	—	Charles H. Gilbert—41
9/25/58	2	—	2	—	" " " "
10/21/58	2	—	2	—	Makua—14
11/20/58	2	—	2	—	Hugh M. Smith—48
12/18/58	2	—	2	—	" " " —49
Total	31	824	33	260	

four contained *R. laevis* larvae (Table 2). In addition to the specimens found in the plankton samples, I examined nine juvenile *R. laevis* (12–2.5 mm T.L.) which were washed up at Maili, Oahu, where they were collected by Mr. K. Ego of the Hawaii Division of Fish and Game, during May 1959; and an adult female (335 mm T.L.) specimen collected from the stomach of

Table 3. Summary of Data on the Ontogeny of *Ranzania laevis*

Panel A.—Selected morphological characters of *R. laevis* collected from the central North Pacific compared with the description of *R. laevis* larvae from the Sargasso Sea.

	Present study	Schmidt 1932 Fig. 197
Egg length in mm.	-	1.3–1.4
First larva		
Total length in mm	1.5–1.7	1.7
Spines	absent	absent
Caudal region	well developed	well developed
Second larva		
Early stage		
Total length in mm	1.8–2.2	1.8–2.4
Paired spines	7[1]	—
Unpaired spines	6	—
Caudal region	beginning to atrophy	beginning to atrophy
Middle stage		
Total length in mm	2.3–4.5	2.4–3.5
Paired spines	7	—
Unpaired spines	6	—
Caudal region	atrophying	atrophying
Late stage		
Total length in mm	4.6–8.0	8.0
Spines	diminishing in number and size	diminishing in number and size
Caudal region	greatly reduced	greatly reduced
Caudal fin	absent	absent

Panel B.—Morphometric and meristic data on juvenile *R. laevis* from Hawaiian waters

	Total length (snout to outer margin of caudal fin)	Fin ray counts				Vertebral count	Depth measured bisecting pectoral	depth/length
		P	D	A	C			
	mm.						mm.	
Early stage	12.0	13	18	18	21	—	8.5	.71
	14.2	13	18	18	20	—	8.5	.60
	18.5	13	18	18	20	—	10.0	.54
	23.0	13	18	18	21	—	10.5	.46
Late stage[2]	62.6	13	18	19	21	—	18.0	.29
	69.8	13	18	19	21	—	17.0	.24
	76.0	13	17	19	21	8 + 10	19.1	.25
	77.4	13	18	19	21	8 + 10	20.0	.26
	82.5	13	18	19	19	—	21.0	.25

Panel C.—Vertebral counts and depth/length relations of adult *R. laevis* from Hawaiian waters and specimen described from the Atlantic

	Total length (snout to outer margin of caudal fin)	Standard length	Fin ray counts				Vertebral count	Depth measured bisecting pectoral	depth/length
			P	D	A	C			
	mm.	mm.						mm.	
Adult[3]	335	321	13	damaged			8 + 10	121	.36 or .38[4]
Fraser-Brunner 1951:94	—	—	—	—			8 + 10 or 11	—	< .50

[1] An additional pair of poorly developed spines is present above orbit.
[2] Washed up on Maili Beach, Oahu.
[3] Found in stomach of marlin, *Makaira* sp., examined at United Fish Market, Oahu, 10/13/60.
[4] Using total length or standard length, respectively.

a marlin, *Makaira* sp., at the United Fish Market, Honolulu, on October 10, 1959.

According to Fraser-Brunner (1951, *Bull. British Mus. Nat. Hist. 1(6):96*), two subspecies of *R. laevis* can be recognized: *R. l. makua* Jenkins in the Pacific and *R. l. laevis* (Pennant) in the Atlantic. Major adult morphological features discussed by Fraser-Brunner are carapace depth and the position of the pectoral fin axil. For *R. l. makua* he reports that carapace depth is greater than half the length, and the axil is located above the center of the eye. In *R. l. laevis* carapace depth is reported less than half the length, and the pectoral fin axil is located below the center of the eye. The adult specimen collected during the present study agreed on these points with the description of *R. l. laevis* given by Fraser-Brunner (Table 3, panel C).

The developmental stages of *R. laevis* found in the plankton samples were compared to the descriptions by Schmidt (1932, *Dana's Togt omkring Jorden: 250–5*) and Tortonese (1956, *Fauna e Flora del Golfo di Napoli, Monog. 38: 965–71*). Excellent agreement was found between the lengths and changes in form of the caudal region at various larval stages as given by Schmidt (*ibid.*, fig. 197) and as seen in my specimens (table 3, panel A). The number of spines, seven paired and six unpaired, found in specimens measuring 2.3–4.5 mm was in agreement with the number found by Tortonese (*ibid.*, 970) in a 2.8-mm specimen collected from the Strait of Messina.

Perhaps some of the confusion found in the literature regarding the nomenclature of *R. laevis* is attributable to the marked changes in form which are characteristic of this fish. The number of pectoral fin rays (13) and the vertebral count (8 + 10) of the juvenile *R. laevis* collected from the beach at Maili, Oahu, are in agreement with corresponding counts given by Fraser-Brunner for adult specimens. However, the depth/length ratio of these juvenile specimens (Table 3, panel B) varies from 0.71 in a 12-mm (T.L.) specimen to 0.25 in an 82.5-mm individual, indicating a change in body form with increase in length. Carapace depth in the older specimens of *R. laevis* is less than half the length, as evidenced from the 335 mm adult collected during the present study, in which the depth/length ratio was found to be <0.50 (Table 3, panel C). Although only one adult was examined, the resulting measurements, when considered with the similarity in larval development between Atlantic specimens and the present series of Pacific specimens, suggest that *R. laevis* is distributed in both Atlantic and Pacific waters.

The only definite record regarding spawning grounds of *R. laevis* is that of Schmidt (1921, *Nature, Lond. 107:76–79*), who reported that viable *R. laevis* eggs (referred to as *R. truncata*) were collected from depths of approximately 100 m in the Sargasso Sea and hatched aboard the *Dana*. In the present study *R. laevis* larvae were collected in varying numbers throughout the entire survey region with no apparent concentration in any one sector (fig. 1). The greatest numbers of *R. laevis* were found in plankton samples collected during late winter and early spring (table 1) in the oceanographic survey series, and during January and February in the IGY collections (table 2). Considerably greater numbers of *R. laevis* were found in the daylight than in the night samples. Abundance of *R. laevis* in all stages of larval development from January to April indicated that considerable spawning had occurred. Absence of appreciable numbers of larval stages during other months of sampling suggests that *R. laevis* spawns only during the late winter and early spring in the Hawaiian region.

In this connection it is noted that the adult ♀ *R. laevis* collected at the United Fish Market, Oahu, in October 1960 contained a large number of developing opaque yellowish ova measuring 0.5 mm. in diameter.

Whether the juvenile *R. laevis* washed up at Maili, Oahu, were members of the 1959 year-class is open to speculation in the absence of adequate growth data.

I am indebted to Messrs. Gary Miller and Edward Kamaura of the HBL for their assistance in the tedious work of separating *R. laevis* from other plankton constituents, and also to Mr. Wilvan G. Van Campen of the HBL staff for his translation of pertinent passages in Danish and Italian publications.—KENNETH SHERMAN, *United States Department of the Interior, Bureau of Commercial Fisheries Biological Laboratory, Honolulu, Hawaii.*

[illegible]

Oceanographic and Biological Data, Hawaiian Waters, January — October 1959

SPECIAL SCIENTIFIC REPORT — FISHERIES No. 396

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

United States Department of the Interior, Stewart Udall, Secretary
Fish and Wildlife Service, Clarence F. Pautzke, Commissioner
Bureau of Commercial Fisheries, Donald L. McKernan, Director

OCEANOGRAPHIC AND BIOLOGICAL DATA, HAWAIIAN WATERS,

JANUARY - OCTOBER 1959

By

Kenneth Sherman, Fishery Research Biologist
and
Robert P. Brown, Oceanographer
Bureau of Commercial Fisheries Biological Laboratory
Honolulu, Hawaii

March 3, 1849

United States Fish and Wildlife Service
Special Scientific Report: Fisheries No. 396

Washington, D. C.

December 1961

ABSTRACT

This report contains the biological and oceanographic data collected during five cruises in the central North Pacific by the Bureau of Commercial Fisheries research vessels *Hugh M. Smith* and *Charles H. Gilbert*. Participating scientists collected oceanographic and biological data designed to determine the distribution of surface water types and the associated biota, particularly skipjack tuna *Katsuwonus pelamis* (Linnaeus). The area investigated was between longitudes 155° and 170° W. at latitudes 15° to 26° N.

CONTENTS

Page
Introduction 1
Field party personnel. 1
Field procedures 5
    Bathythermograph and meteorological observations. 5
    Light penetration and water color 5
    Zooplankton collections 5
    Surface fish school, bird flock, and aquatic mammal sightings 5
    Longline fishing. 6
    Surface trolling. 6
    Tagging 6
Laboratory procedures. 6
    Salinity determination. 6
    Phosphate determination 6
    Zooplankton 6
Literature cited 7

ILLUSTRATIONS

Figures 1a-g. Vessel tracks for *Hugh M. Smith* cruises 50 and 51 and *Charles H. Gilbert* cruises 44, 45, and 46 2

TABLES

Page

1. Cruise areas and periods 8
2. Summary of observations at bathythermograph lowerings, *Hugh M. Smith* cruise 50 9
3. Summary of observations at bathythermograph lowerings, *Hugh M. Smith* cruise 51 15
4. Summary of observations at bathythermograph lowerings, *Charles H. Gilbert* cruise 44 . . 21
5. Summary of observations at bathythermograph lowerings, *Charles H. Gilbert* cruise 45 . . 27
6. Summary of observations at bathythermograph lowerings, *Charles H. Gilbert* cruise 46 . . 30
7. Summary of weather observations (USWB 1210-F), *Hugh M. Smith* cruise 50 34
8. Summary of weather observations (USWB 1210-F), *Hugh M. Smith* cruise 51 38
9. Summary of weather observations (USWB 1210-F), *Charles H. Gilbert* cruise 44 42
10. Summary of weather observations (USWB 1210-F), *Charles H. Gilbert* cruise 45 46
11. Summary of weather observations (USWB 1210-F), *Charles H. Gilbert* cruise 46 49
12. Light penetration and water color 52
13. Zooplankton station positions and sample weights, *Hugh M. Smith* cruise 50 53
14. Zooplankton station positions and sample weights, *Hugh M. Smith* cruise 51 54
15. Zooplankton station positions and sample weights, *Charles H. Gilbert* cruise 44 55
16. Zooplankton station positions and sample weights, *Charles H. Gilbert* cruise 45 56
17. Zooplankton station positions and sample weights, *Charles H. Gilbert* cruise 46 57
18. Major zooplankton group composition of selected samples. 58
19. Record of surface fish school, bird flock, and aquatic mammal sightings, *Hugh M. Smith* cruise 50 61
20. Record of surface fish school, bird flock, and aquatic mammal sightings, *Hugh M. Smith* cruise 51 62
21. Record of surface fish school, bird flock, and aquatic mammal sightings, *Charles H. Gilbert* cruise 44 63
22. Record of surface fish school, bird flock, and aquatic mammal sightings, *Charles H. Gilbert* cruise 45 64
23. Record of surface fish school, bird flock, and aquatic mammal sightings, *Charles H. Gilbert* cruise 46 67
24. Summary of longline catch data 68
25. Summary of surface trolling catch data 69
26. Summary of skipjack tagging 70
27. Common and scientific names of fishes reported 71

OCEANOGRAPHIC AND BIOLOGICAL DATA, HAWAIIAN WATERS,

JANUARY - OCTOBER, 1959

By

Kenneth Sherman, Fishery Research Biologist
and
Robert P. Brown, Oceanographer
Bureau of Commercial Fisheries Biological Laboratory
Honolulu, Hawaii

During 1959 there were five cruises in the central Pacific area between latitude 15° N. and 26° N., longitude 145° W. to 170° W. (table 1; fig. 1) by research vessels of the Bureau of Commercial Fisheries Biological Laboratory, Honolulu, Hawaii.

The purpose of these cruises was twofold: (1) to delineate the boundaries between the North Pacific Central, the zone of intermediate salinity, and the North Pacific Equatorial water types[1]; and (2) to monitor the seasonal movements of those boundaries and of the associated marine biota, particularly the skipjack tuna, Katsuwonus pelamis (Linnaeus).

The present report contains a record of observed physical and biological data from the five 1959 cruises. They are presented without analysis.

FIELD PARTY PERSONNEL

Hugh M. Smith - Robert E. K. D. Lee, Acting Master
  Cruise 50
    Gunter R. Seckel, Field Party Chief
    Daniel T. Yamashita, Fishery Research Biologist
    Arthur O. Oishi, Fishery Aid

  Cruise 51
    Herbert H. Shippen, Field Party Chief
    Walter M. Matsumoto, Fishery Research Biologist
    Fred Hertlein, Physical Science Aid

Charles H. Gilbert - William T. Tanaka, Master
  Cruise 44
    Kenneth D. Waldron, Field Party Chief
    Herbert H. Shippen, Fishery Research Biologist
    Fred Hertlein, Physical Science Aid

  Cruise 45
    Donald W. Strasburg, Field Party Chief
    Eugene L. Nakamura, Fishery Research Biologist
    Reginald M. Gooding, Fishery Research Biologist
    Robert A. Stevenson, Jr., Fishery Research Biologist
    Heeny S. H. Yuen, Fishery Research Biologist
    Richard J. Hansen, Fishery Aid

  Cruise 46
    Eugene L. Nakamura, Field Party Chief (Sept. 15-16)
    Donald W. Strasburg, Field Party Chief (Sept. 17-28)
    Richard S. Shomura, Field Party Chief (Sept. 29-Oct. 18)
    Robert A. Stevenson, Jr., Fishery Research Biologist
    Daniel T. Yamashita, Fishery Research Biologist
    Howard O. Yoshida, Fishery Research Biologist
    Richard J. Hansen, Fishery Aid

---

[1] Seckel (1961, in press) discusses the difference between water masses, as described by Sverdrup et al. (1942, ch. 15), and water types. He states, "The chief distinction between water types and masses is that the former are under the direct influence of the physical processes taking place at the sea surface whereas the latter are not. One would therefore expect relatively large seasonal temperature and salinity changes in the surface water types. The position of their boundaries would also be subject to changing wind stresses, so that they would not always coincide with the corresponding water mass boundaries."

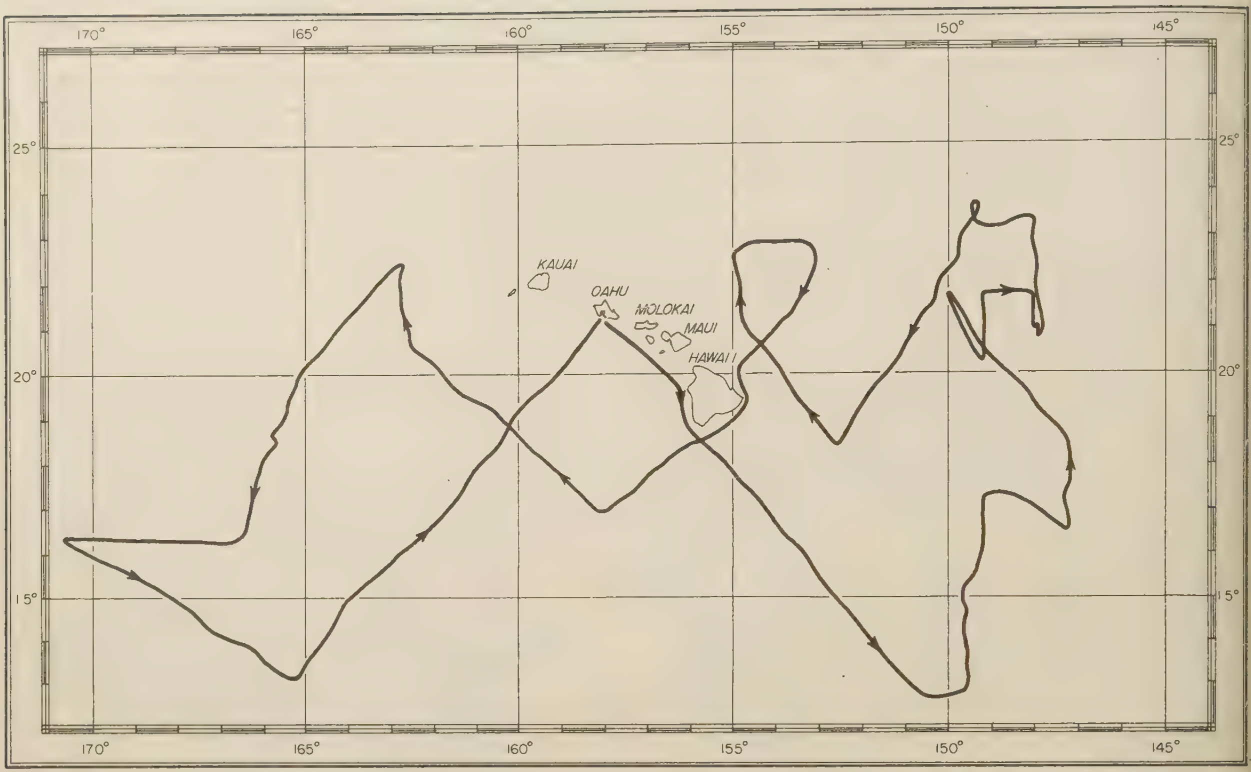

170°
165°
160°
155°
150°
145°
25°
20°
15°
KAUAI
OAHU
MOLOKAI
MAUI
HAWAII

Figure 1a. --Vessel track of *Hugh M. Smith* cruise 50, Jan. 7-Feb. 10, 1959.

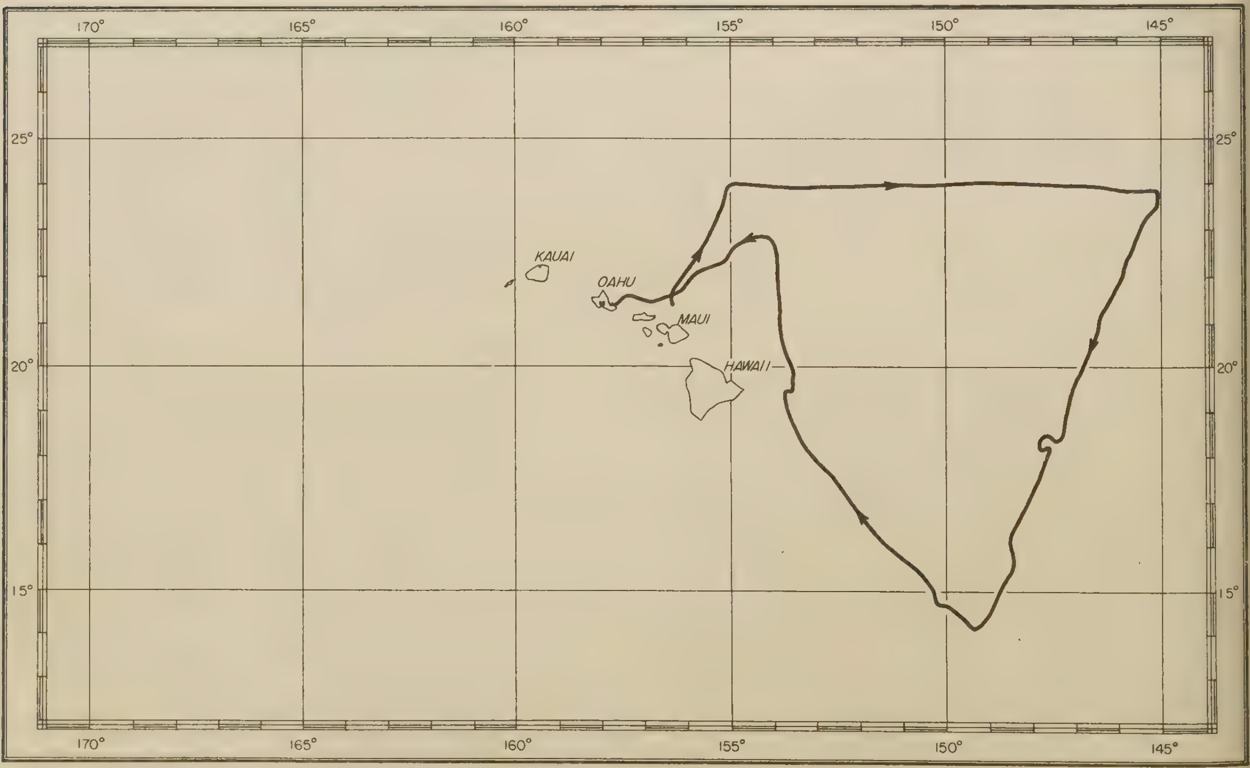

170°
165°
160°
155°
150°
145°
25°
20°
15°
KAUAI
OAHU
MAUI
HAWAII

Figure 1b. --Vessel track of *Hugh M. Smith* cruise 51, Mar. 5-19, 1959.

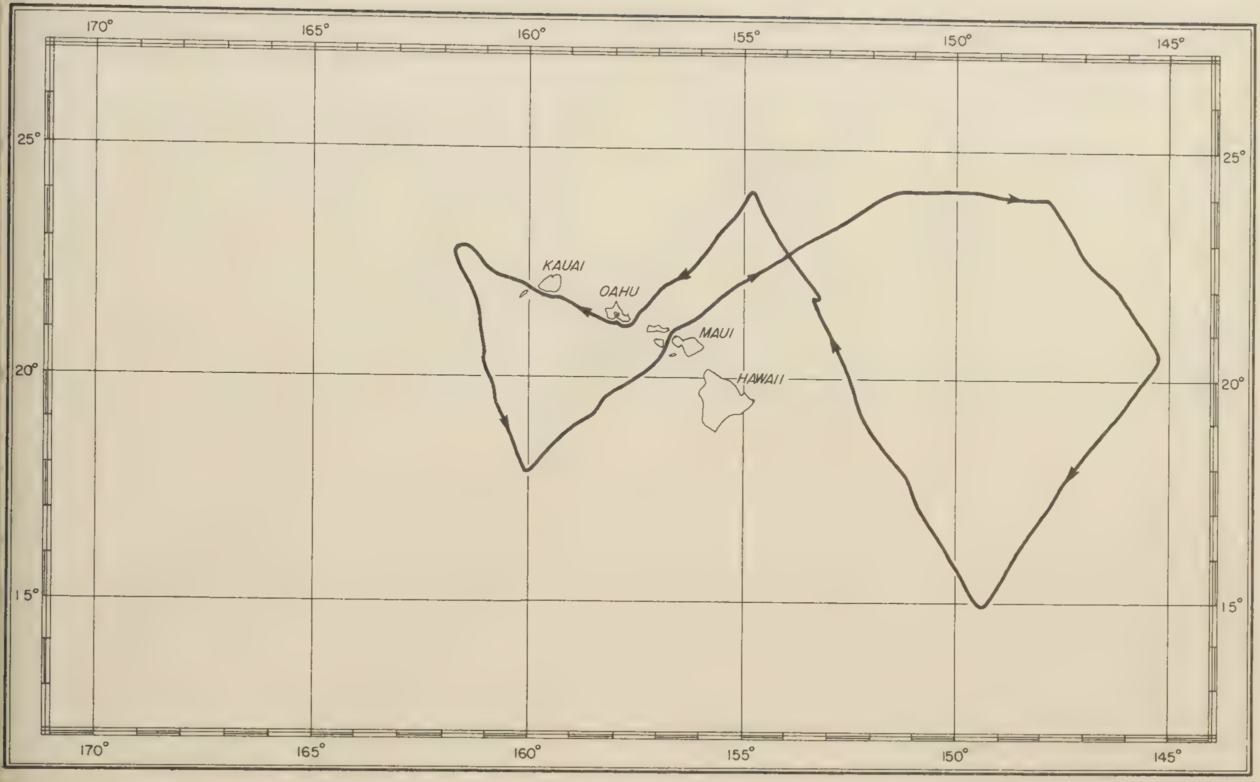

170°
165°
160°
155°
150°
145°
25°
20°
15°
KAUAI
OAHU
MAUI
HAWAII

Figure 1c.--Vessel track of Hugh M. Smith cruise 51, Mar. 21-Apr. 6, 1959.

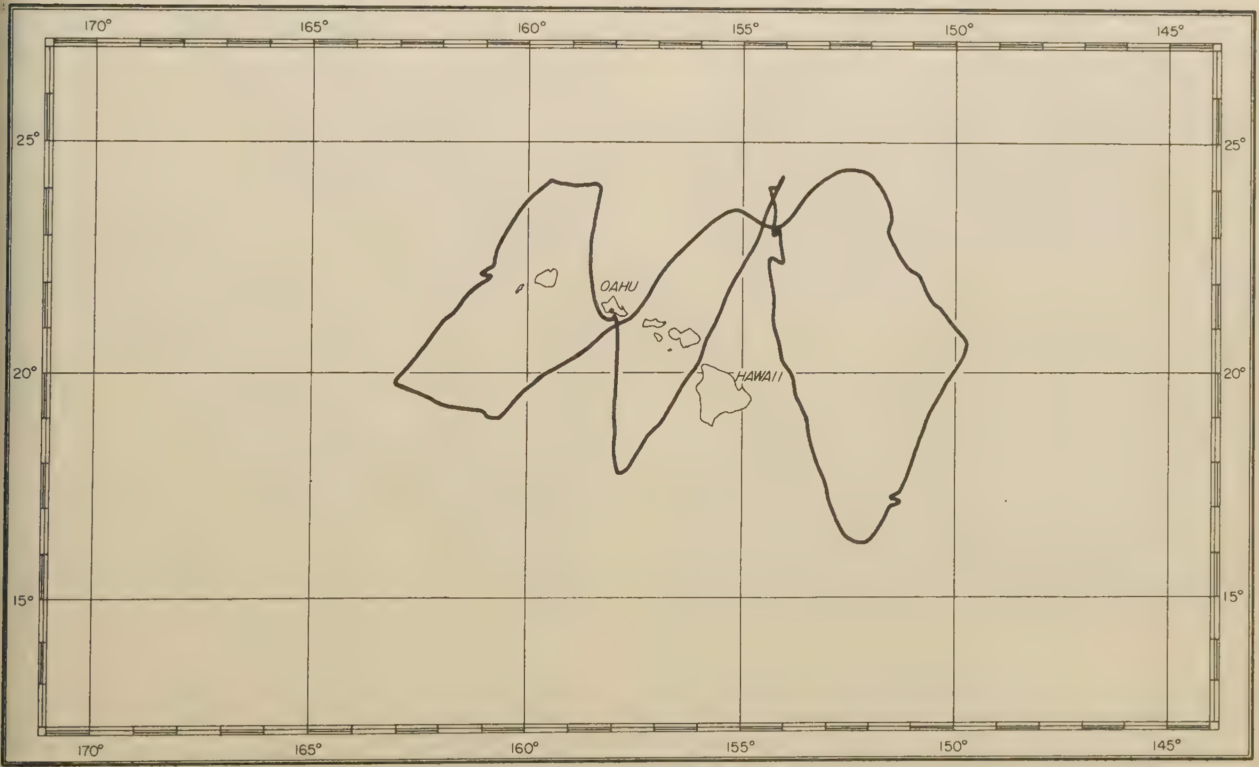

170°
165°
160°
155°
150°
145°
25°
20°
15°
OAHU
HAWAII

Figure 1d.--Vessel track of Charles H. Gilbert cruise 44, Apr. 30-May 18, 1959.

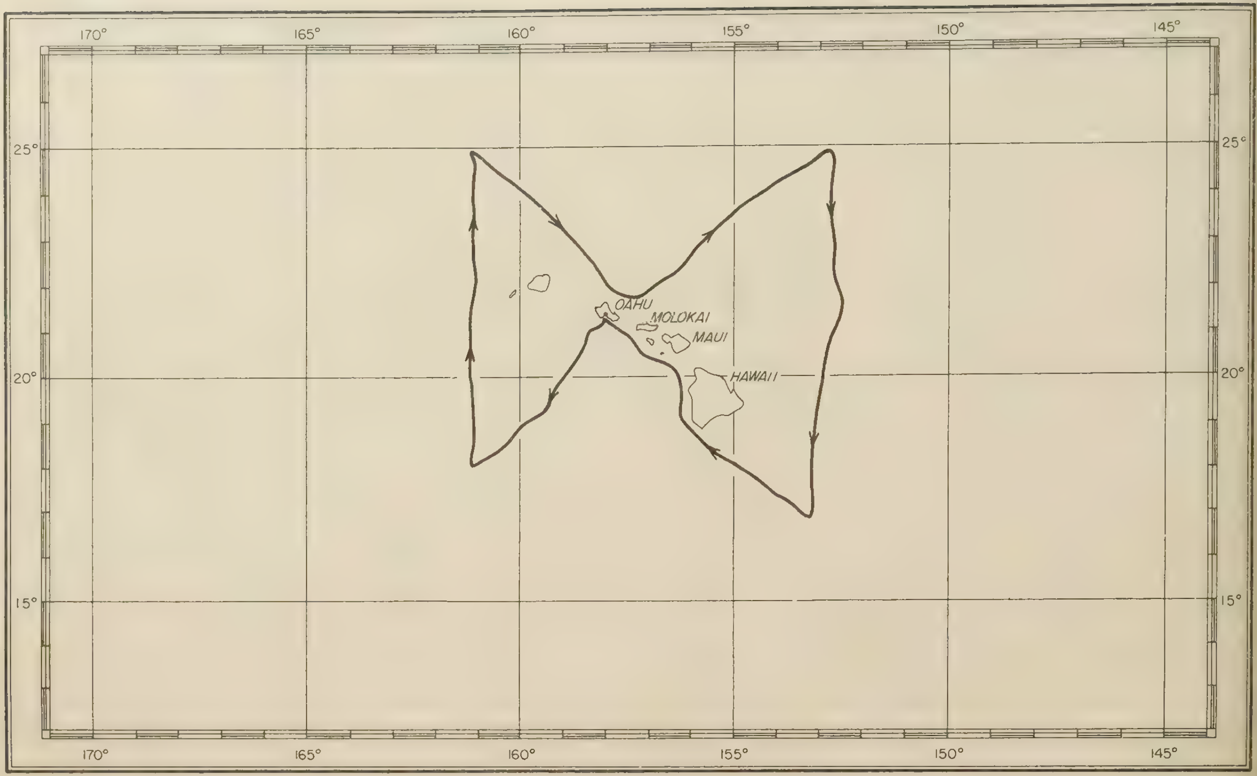

170°
165°
160°
155°
150°
145°
25°
20°
15°
OAHU
MOLOKAI
MAUI
HAWAII

Figure 1e. --Vessel track of Charles H. Gilbert cruise 44, May 20-June 1, 1959.

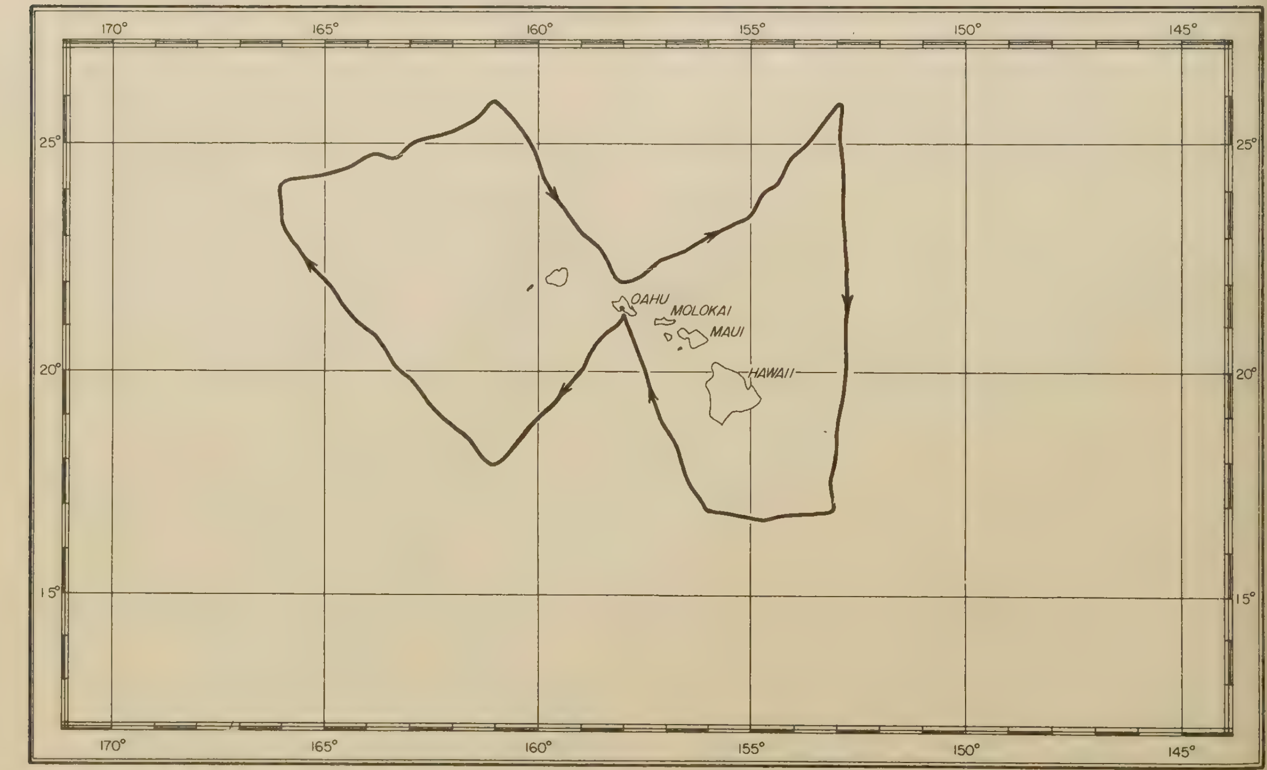

170°
165°
160°
155°
150°
145°
25°
20°
15°
OAHU
MOLOKAI
MAUI
HAWAII

Figure 1f. --Vessel track of Charles H. Gilbert cruise 45, July 15-31, 1959.

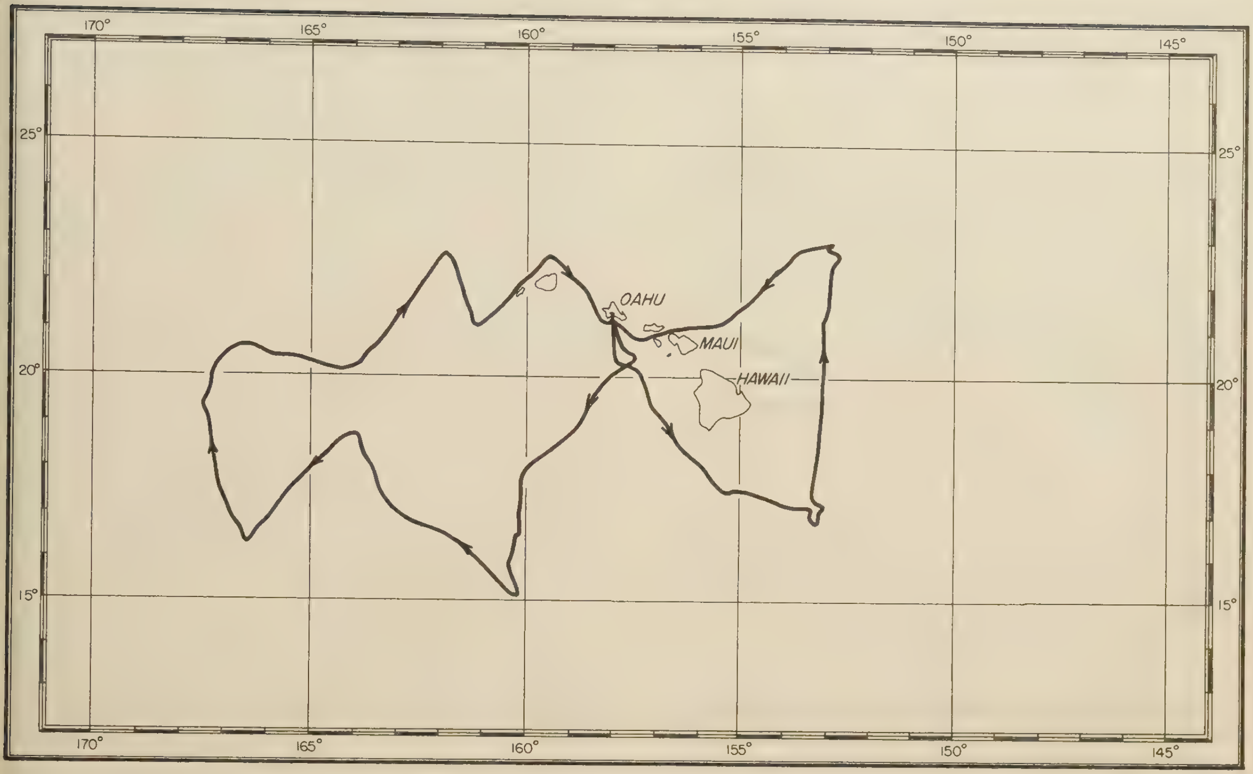


Figure 1g.--Vessel track of Charles H. Gilbert cruise 46, Sept. 29-Oct. 18, 1959.

FIELD PROCEDURES

Bathythermograph and Meteorological Observations

Bathythermograph (BT) lowerings were made every 3 hours on Hugh M. Smith cruises 50 and 51, and approximately every 30 miles on Charles H. Gilbert cruises 44, 45, and 46. The observations of weather and sea at each BT lowering appear in tables 2 to 6. The BT slides, prior to deposition in the U.S. Navy Hydrographic Office, were processed at the Laboratory by the method described by Callaway (1957).

Weather observations were recorded at 0000, 0600, 1200, and 1800 GCT daily. These data are presented in tables 7 to 11 (U.S.Weather Bureau Form 1210-F). Recording and coding follow the "Manual of Marine Meteorological Observations" (U.S. Weather Bureau, 1959).

Light Penetration and Water Color

Secchi disc observations and Forel water color estimations from Hugh M. Smith cruises 50 and 51 and Charles H. Gilbert cruises 45 and 46 are tabulated in table 12. These observations were taken at local apparent noon.

Zooplankton Collections

Of the 139 plankton hauls, 107 were 1/2-hour, 0- to 60-m. oblique hauls at approximately 2100 hours. In addition, 24 surface tows of 20-minute duration were taken during Charles H. Gilbert cruise 45 to collect larval tunas for serological studies. On Charles H. Gilbert cruise 46, five 1/2-hour surface hauls were taken across a temperature discontinuity encountered south of the island of Molokai. Three oblique 0- to 140-m. hauls were taken during Hugh M. Smith cruise 50 for comparison with plankton hauls taken at similar depths during previous cruises. Zooplankton sample weights are given in tables 13-17. The major group composition for selected samples is given in table 18.

All plankton hauls were made using a 1-meter net with body of No. 656 Nitex, aperture widths 0.66 mm., and with cod end of No. 308 Nitex, aperture widths 0.31 mm. (King and Demond, 1953).

Surface Fish School, Bird Flock, and Aquatic Mammal Sightings

A watch was maintained for surface fish schools, birds, and aquatic mammals during the daylight hours. Summaries of these observations are presented in tables 19 to 23.

Longline Fishing

During four of the cruises, 25 longline stations were occupied. No longlining was undertaken during Charles H. Gilbert cruise 45. The longline gear used was a modification of the 11-hook basket described by Mann (1955), alternating floatline lengths of 10, 5, and 0 fathoms (in the last case the mainline was tied directly to the buoy) instead of the usual 10-fathom length. Positions and species composition of the catch are presented in table 24. Common and scientific names of fish caught are listed in table 27.

Surface Trolling

Two lines were trolled during daylight hours. A summary of surface trolling results for the five cruises is presented in table 25.

Tagging

A total of 236 skipjack were tagged with the all-plastic dart-type tags described by Yamashita and Waldron (1958). A summary of skipjack tagging results is presented in table 26.

LABORATORY PROCEDURES

Salinity Determination

The surface salinity samples obtained at each bathythermograph lowering were analyzed on shipboard using a modification of the Knudsen method (Van Landingham, 1957). A comparison of the shipboard and the subsequent laboratory determinations showed no significant difference between the two. The salinity data are incorporated in tables 2 to 6.

Phosphate Determination

Surface phosphate samples were collected on Hugh M. Smith cruises 50 and 51 and on Charles H. Gilbert cruises 44 and 46. These samples were analyzed by the hydrazine sulphate modification of Deniges' method (King, Austin, and Doty, 1957). The results are in tables 2, 3, 4, and 6.

Zooplankton

For all cruises, the methods for determining zooplankton abundance and composition described by King and Hida (1957) were followed with two exceptions:

1. All organisms above 5 cm. in longest dimension, plus the nonfood[2] organisms 2-5 cm. in longest dimension, were removed from the sample and not included in the weight or group count data.

2. The weights of plankton expressed in g./1,000 m.^{3} (tables 13-17) were converted from volumetric displacement values for Hugh M. Smith cruises 50 and 51 and Charles H. Gilbert cruise 44. No significant difference was found between plankton volumes determined by volumetric displacement and those weighed directly after draining in a 56XXX grit gauze sock. This conclusion is based on a regression analysis in which 63 plankton samples ranging in displacement volume from less than 5 cc. to more than 200 cc. were drained, weighed, and volumetrically measured by water displacement. The regression equation of weight on volume was $Y = 0.9954X$. The deviation from a theoretical one-to-one basis was 0.0046 (E. C. Jones, personal communication).

Five stations from each cruise, except Hugh M. Smith cruise 50, were selected for group-count analysis (phylum to order) following the method described by Jones (McGary, Jones, and Austin, 1956). For Hugh M. Smith cruise 50, six stations were analyzed. The stations chosen were situated in one of three water types characterized by comparatively high salinity (> 34.9 ‰), intermediate salinity (34.5 - 34.9 ‰), or low salinity (< 34.5 ‰). The group composition and the percentage-occurrence of each group are presented in table 18.

---

[2] Siphonophores, medusae, ctenophores, heteropods, and tunicates, as described by King and Hida (1957).

LITERATURE CITED

CALLAWAY, RICHARD J.
1957. Oceanographic and meteorological observations in the northeast and central North Pacific, July-December 1956. U.S. Fish and Wildlife Service, Special Scientific Report--Fisheries 230, 49 p.

KING, JOSEPH E., and JOAN DEMOND
1953. Zooplankton abundance in the central Pacific. U.S. Fish and Wildlife Service, Fishery Bulletin 82, vol. 54, p. 111-144.

_______, and THOMAS S. HIDA
1957. Zooplankton abundance in the central Pacific, Part II. U.S. Fish and Wildlife Service, Fishery Bulletin 118, vol. 57, p. 365-395.

_______, THOMAS S. AUSTIN, and MAXWELL S. DOTY
1957. Preliminary report on expedition EASTROPIC. U.S. Fish and Wildlife Service, Special Scientific Report -- Fisheries 201, 155 p.

MANN, HERBERT J.
1955. Construction details of improved tuna long-line gear used by Pacific Oceanic Fishery Investigations. U.S. Fish and Wildlife Service, Commercial Fisheries Review, vol. 17, no. 12, p. 1-10. [Also as Separate No. 422]

McGARY, JAMES W., EVERET C. JONES, and THOMAS S. AUSTIN
1956. Mid-Pacific oceanography, Part IX, Operation NORPAC. U.S. Fish and Wildlife Service, Special Scientific Report--Fisheries 168, 127 p.

SECKEL, GUNTER R.
1961. An atlas of the oceanographic climate of the Hawaiian Islands region. U.S. Fish and Wildlife Service, Fishery Bulletin (in press).

SVERDRUP, HAROLD U., MARTIN W. JOHNSON, and RICHARD H. FLEMING
1942. The oceans, their physics, chemistry, and general biology. Prentice-Hall, Inc., New York, 1,087 p.

U.S. NAVY HYDROGRAPHIC OFFICE
1956. Bathythermograph observations. U.S. Navy Hydrographic Office Pub. 606-c, 2nd edition, 16 p.

U.S. WEATHER BUREAU
1960. Manual of marine meterorological observations. U.S. Weather Bureau, Circular M, 10th edition. 127 p.

VAN LANDINGHAM, JOHN W.
1957. A modification of the Knudsen method for salinity determination. Journal du Conseil Permanent International pour l'Exploration de la Mer, vol. 22, no. 2, p. 174-179.

YAMASHITA, DANIEL T., and KENNETH D. WALDRON
1958. An all-plastic dart-type fish tag. California Fish and Game, vol. 44, no. 4, p. 311-317.

Table 1.--Cruise areas and periods

Vessel	Cruise	Period, 1959	General Area
Hugh M. Smith	50	Jan. 9-Feb. 10	13°N. to 23°N.; 147°W. to 170°W.
Hugh M. Smith	51	March 3-March 19 March 21-April 6	14°N. to 24°N.; 146°W. to 157°W. 15°N. to 24°20'N.; 145°W. to 162°W.
Charles H. Gilbert	44	April 30-May 18 May 20-June 1	15°50'N. to 24°30'N.; 150°W. to 163°W. 17°N. to 25°N.; 155°W. to 161°W.
Charles H. Gilbert	45	July 6-July 14 July 15-July 31	Local Hawaiian Waters 17°N. to 26°N.; 153°W. to 166°W.
Charles H. Gilbert	46	Sept. 15-Sept. 26 Sept. 29-Oct. 18	Local Hawaiian Waters 15°N. to 23°N.; 153°W. to 167°30'W.

Table 2.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 50
(Recording and coding of data follows U.S. Navy Hydrographic Office, 1956.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Barometer (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO4-P, (ug. at./l.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T.)	Amt.		
1	0310	1/10	20°17'	156°02'	77.0	27	3	78.0	72.0	1011	02	6	6	9	0	04	2	34.72	
2	0705	1/10	19°39'	156°10'	76.1	20	9	77.0	73.5	1013	02	X[1]	X	9	0		0	34.74	
3	1630	1/10	18°55'	156°00'	76.3	04	3	76.5	72.1	1012	02	6	6	9	0	10	1	34.57	
4	1900	1/10	18°38'	155°45'	76.7	15	3	78.5	74.2	1014	02	4,8	6	9	0	10	1	34.61	
5	2100	1/10	18°26'	155°33'	77.3	15	5	77.5	73.6	1014	02	4,8	6	9	0	10	1	34.53	
6	0000	1/11	18°06'	155°15'	78.1	15	4	79.4	73.6	1012	02	4,8	3	9	0	15	1	34.44	
7	0300	1/11	17°48'	154°59'	77.2	15	5	77.1	73.2	1012	01	4,8	2	9	1	15	1	34.72	
8	0600	1/11	17°29'	154°42'	76.9	11	7	76.7	73.5	1013	02	4	2	9	1	X	X	34.72	
9	0900	1/11	17°10'	154°26'	76.5	09	6	76.9	73.8	1014	02	4	2	9	1	15	1	34.74	
10	1200	1/11	16°48'	154°08'	77.8	08	10	76.8	73.2	1012	02	X	1	9	2	15	1	34.36	
11	1500	1/11	16°26'	153°49'	76.9	08	10	76.9	73.6	1012	02	X	2	9	2	15	1	34.52	
12	1800	1/11	16°06'	153°32'	77.3	11	12	78.0	73.7	1013	15	4,6	6	9	2	11	2	34.64	
13	2100	1/11	15°46'	153°14'	77.5	09	15	78.0	73.0	1012	02	4,6	6	9	2	11	2	34.64	
14	0000	1/12	15°25'	152°57'	77.0	08	14	78.0	73.9	1010	03	4,6	7	9	2	11	2	34.72	
15	0300	1/12	15°04'	152°40'	76.8	10	12	77.5	73.5	1010	02	4,6	7	9	2	11	2	34.72	
16	0600	1/12	14°43'	152°21'	76.6	08	14	77.3	74.0	1012	02	X	7	9	2	11	2	34.74	
17	0900	1/12	14°25'	152°07'	77.3	08	16	77.2	74.1	1012	01	X	5	9	3	11	4	34.49	
18	1200	1/12	14°07'	151°53'	77.9	08	16	78.0	74.2	1010	02	X	2	9	3	11	4	34.16	
19	1500	1/12	13°49'	151°38'	77.5	09	17	77.9	73.9	1009	02	X	2	9	3	11	4	34.23	
20	1800	1/12	13°30'	151°22'	78.2	09	18	79.0	74.5	1010	02	4,6	5	9	3	11	4	34.05	
21	2100	1/12	13°14'	151°06'	78.7	10	21	79.4	75.0	1009	02	4,6	3	9	4	10	4	34.08	
22	0000	1/13	12°57'	150°50'	78.6	11	21	79.2	74.8	1006	02	4,6	3	9	4	11	4	33.97	
23	0300	1/13	12°41'	150°38'	79.2	11	18	79.8	75.0	1008	01	4	2	9	4	11	4	33.92	
24	0600	1/13	12°42'	150°24'	78.9	12	16	79.4	74.8	1008	03	X	4	9	4	11	4	33.97	
25	1200	1/13	12°46'	149°55'	78.1	12	20	79.3	72.9	1008	02	X	6	9	4	11	4		
26	2145	1/13	12°51'	149°39'	78.4	10	18	80.0	73.5	1009	02	2	8	9	4	11	4	34.02	
27	0300	1/14	13°04'	149°33'	78.1	11	18	78.7	73.2	1008	02	1	8	9	4	11	4	33.93	
28	0600	1/14	13°30'	149°35'	78.1	11	14	78.5	73.5	1011	02	X	2	9	3	11	4	33.88	
29	0900	1/14	13°51'	149°34'	78.4	10	13	78.5	74.3	1011	02	X	2	9	3	11	4	33.93	
30	1200	1/14	14°18'	149°34'	78.0	10	13	78.0	74.4	1010	02	X	2	9	3	11	4	34.11	
31	1500	1/14	14°45'	149°35'	77.8	07	13	77.9	74.6	1010	02	X	4	9	3	11	4	34.15	
32	2225	1/14	15°04'	149°41'	78.0	08	12	78.1	76.0	1011	03	6	8	8	2	09	3	34.15	
33	0305	1/15	15°17'	149°31'	77.8	07	10	78.5	75.6	1012	02	6	8	9	2	09	3	34.12	
34	0600	1/15	15°41'	149°17'	77.8	10	14	78.1	75.5	1013	02	X	7	9	2	09	3	34.19	
35	0900	1/15	16°02'	149°08'	77.9	12	14	77.9	75.1	1013	02	X	7	8	2	09	3	34.21	
36	1200	1/15	16°30'	149°09'	77.3	13	14	77.7	75.0	1012	02	X	5	9	2	10	1	34.12	
37	1500	1/15	16°57'	149°11'	77.1	14	13	77.6	75.0	1012	02	X	X	9	2	10	1	34.12	
38	2205	1/15	17°17'	149°18'	77.5	19	08	79.0	76.0	1011	02	6	7	9	2	10	1	34.06	
39	0600	1/16	17°15'	148°38'	77.5	21	10	78.1	75.1	1012	80	X	8	9	2	10	1	34.24	
40	1200	1/16	16°56'	147°51'	77.0	03	14	75.0	71.5	1010	02	X	6	9	2	08	1	34.05	

[1] X indicates that no observation was recorded.

Table 2.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 50 (con.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Barometer (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO_4-P, (ug. at./l.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T.)	Amt.		
41	2200	1/16	16°37'	147°12'	77.0	13	21	76.3	74.4	1009	01	6,4	7	9	3	14	4	34.18	0.34
42	0300	1/17	16°52'	147°12'	76.9	12	12	76.2	72.1	1008	15	6,4	6	9	2	31	4	34.07	
43	0600	1/17	17°18'	147°16'	76.5	13	14	76.4	72.1	1010	01	8	2	9	2	31	4	34.14	
44	0900	1/17	17°36'	147°12'	76.9	13	14	76.9	72.0	1010	02	8	2	9	2	31	4	34.12	
45	1200	1/17	18°05'	147°12'	77.2	14	17	76.2	72.0	1008	02	X	2	9	3	12	4	34.10	
46	1500	1/17	18°33'	147°12'	76.9	15	16	76.1	71.2	1008	02	X	4	9	3	12	4	34.03	
47	1800	1/17	18°57'	147°32'	77.1	15	20	76.8	70.0	1010	02	6	7	9	3	31	4	34.04	
48	2100	1/17	19°18'	147°52'	76.4	16	19	77.9	70.4	1010	02	6,4	2	9	3	31	4	34.19	
49	0000	1/18	19°39'	148°12'	76.5	15	23	77.2	71.1	1008	02	4	5	9	3	15	3	34.13	
50	0300	1/18	19°59'	148°35'	76.4	16	22	77.0	71.8	1009	02	4,6	2	9	3	15	3	34.10	
51	0600	1/18	20°20'	148°57'	76.1	16	23	76.9	72.0	1010	02	X	4	9	3	15	3	34.25	
52	0900	1/18	20°38'	149°10'	76.3	15	24	76.7	72.5	1010	02	4	6	9	3	15	3	34.19	
53	1200	1/18	21°02'	149°30'	75.4	16	28	76.4	72.5	1009	02	X	4	9	5	15	4	34.46	
54	1500	1/18	21°26'	149°49'	76.1	16	24	76.5	72.9	1009	02	X	4	9	3	15	4	34.21	
55	1800	1/18	21°50'	150°07'	74.4	16	30	77.9	72.9	1008	14	6	6	9	5	15	4	34.89	
56	1800	1/19	20°21'	149°10'	76.4	16	24	76.2	73.2	1015	02	4,5	7	9	3	15	4	34.14	
57	2100	1/19	20°48'	149°10'	75.6	16	07	78.4	74.2	1024	02	4,5	7	9	2	15	3	34.45	
58	0000	1/20	21°16'	149°12'	76.0	11	18	75.9	74.0	1013	63	0	9	6	2	25	5	34.30	
59	0300	1/20	21°44'	149°14'	75.1	13	13	76.0	73.7	1015	02	4,6	7	9	2	25	5	34.61	
60	0600	1/20	21°48'	148°50'	74.8	15	18	75.4	72.6	1016	60	X	8	8	2	15	3	34.67	
61	0900	1/20	21°46'	148°28'	74.6	14	12	76.1	72.0	1017	00	X	8	8	2	14	3	34.71	
62	1200	1/20	21°46'	148°04'	74.4	16	10	74.9	71.7	1016	02	X	6	9	2	15	3	34.93	
63	1500	1/20	21°22'	148°02'	74.4	34	17	71.1	69.0	1017	63	X	8	X	2	15	3	34.65	
64	1800	1/20	21°00'	148°00'	74.3	05	14	72.6	67.9	1018	14	6	7	9	2	05	1	34.75	
65	2150	1/20	21°02'	148°00'	74.7	11	14	74.0	70.6	1016	01	4,8	2	9	2	06	3	34.78	
66	0310	1/21	20°53'	147°58'	75.5	15	11	76.0	71.0	1015	02	4,8	4	9	2	14	3	34.46	
67	0600	1/21	21°18'	148°01'	74.7	14	10	74.9	71.1	1016	03	4	6	9	2	14	3	34.85	
68	0900	1/21	21°41'	147°59'	74.5	15	07	74.6	71.0	1016	01	4	2	9	2	09	2	34.87	
69	1200	1/21	22°10'	147°59'	74.5	14	10	74.0	70.4	1014	02	8	4	9	2	09	2	34.88	
70	1500	1/21	22°40'	147°59'	74.0	15	10	73.9	70.1	1014	02	8	2	9	2	09	2	34.86	
71	2200	1/21	23°01'	148°03'	72.8	33	06	70.0	68.4	1015	25	6	8	8	2	09	4	34.86	
72	0300	1/22	23°10'	147°58'	72.9	06	06	71.1	68.4	1014	15	4,6	6	9	1	09	4	35.13	
73	0600	1/22	23°13'	148°21'	73.0	16	08	72.7	70.1	1015	02	6	7	9	1	09	4	35.02	
74	0900	1/22	23°11'	148°44'	72.5	19	07	71.5	69.5	1015	02	8,6	6	9	1	22	1	35.10	
75	1200	1/22	23°11'	149°13'	73.5	16	07	71.7	68.2	1014	14	6	8	9	1	26	2	35.01	
76	1500	1/22	23°17'	149°16'	72.5	08	05	72.0	69.7	1015	01	6	2	9	1	11	1	35.04	
77	2210	1/22	23°42'	149°15'	72.9	19	11	73.5	70.3	1016	02	4,6,8	5	9	1	16	2	34.97	
78	0300	1/23	23°39'	149°16'	73.1	28	08	74.0	70.5	1016	02	4,6,8	5	9	1	32	4	34.97	
79	0600	1/23	23°15'	149°30'	74.0	26	12	72.1	67.4	1018	14	6	8	8	1	32	4	35.02	
80	0900	1/23	22°53'	149°42'	73.8	28	10	73.1	70.2	1019	10	4,6,8	4	9	1	32	4	34.90	

Table 2.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 50 (con.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Baro-meter (mb.)	Wea-ther	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO_4-P, (ug. at./l.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T.)	Amt.		
81	1200	1/23	22°29'	149°55'	74.6	33	14	73.0	70.0	1018	02	8	3	9	1	24	1	34.64	
82	1500	1/23	22°04'	150°08'	74.2	34	14	73.0	67.7	1019	01	8	1	9	1	28	2	34.82	
83	1800	1/23	21°38'	150°24'	75.1	03	13	73.9	67.7	1020	02	8	2	9	2	34	2	34.73	
84	2100	1/23	21°13'	150°39'	74.5	04	14	76.0	69.0	1020	02	8	2	9	2	34	5	34.61	
85	0000	1/24	20°50'	150°55'	74.9	04	18	74.6	67.9	1019	02	8	3	9	2	34	4	34.64	
86	0300	1/24	20°23'	151°14'	75.0	03	20	74.7	69.7	1019	02	8	6	9	3	34	4	34.73	
87	0600	1/24	19°56'	151°31'	76.0	04	26	73.9	67.9	1021	02	8	2	9	4	34	4	34.38	0.41
88	0900	1/24	19°40'	151°44'	76.0	05	22	74.2	68.8	1022	02	8	6	9	3	05	4	34.49	
89	1200	1/24	19°16'	152°00'	76.3	06	22	74.5	69.5	1021	03	6,8	7	8	3	05	4	34.41	
90	1500	1/24	18°50'	152°15'	77.0	04	24	74.4	69.6	1020	02	6,8	7	9	3	05	4	34.22	
91	1800	1/24	18°26'	152°32'	76.7	05	22	74.8	70.8	1022	80	0	8	5	3	05	3	34.58	
92	2100	1/24	18°46'	152°51'	77.1	08	22	75.1	72.0	1022	01	4,6	2	9	4	05	3	34.21	
93	0000	1/25	19°08'	153°09'	76.9	08	22	77.0	72.0	1020	02	6,8	6	8	4	05	3	34.24	
94	0300	1/25	19°31'	153°27'	76.7	06	22	75.8	71.1	1020	02	6,8	7	9	4	05	3	34.20	
95	0600	1/25	19°54'	153°45'	76.3	07	20	75.0	70.0	1021	15	6,8	6	9	4	06	3	34.27	
96	0850	1/25	20°11'	153°56'	75.0	07	20	74.6	70.0	1022	02		7	6	4	06	3	34.83	
97	1200	1/25	20°32'	154°12'	75.3	09	18	74.1	70.0	1021	02	6	6	6	3	07	3	34.80	
98	1500	1/25	20°53'	154°29'	74.0	09	19	74.0	69.0	1021	01	8	2	9	3	07	3	34.87	
99	1800	1/25	21°14'	154°45'	74.1	09	19	76.0	71.0	1022	02	6,8	2	9	3	07	3	34.88	
100	2100	1/25	21°44'	154°47'	74.1	09	22	74.9	70.1	1023	16	6,8	6	7	3	32	5	34.99	
101	0000	1/26	22°12'	154°48'	74.1	10	17	74.2	70.4	1020	16	6	7	9	3	10	3	35.01	
102	0300	1/26	22°40'	154°48'	73.5	10	12	73.5	70.5	1021	21	6	7	6	3	10	3	35.06	
103	0600	1/26	22°52'	154°32'	73.8	11	12	73.5	70.4	1022	14	6	7	9	3	09	3	35.05	
104	0900	1/26	22°51'	154°07'	73.6	12	14	73.6	70.9	1023	02	6	5	9	3	11	3	35.07	
105	1200	1/26	22°50'	153°40'	73.0	11	14	73.1	70.0	1022	01	6	3	9	3	09	3	35.07	
106	1500	1/26	22°48'	153°14'	73.0	19	10	71.4	68.0	1022	20	6	6	8	3	09	3	35.16	
107	2200	1/26	22°46'	153°08'	73.2	11	14	72.6	69.0	1022	02	8	2	9	2	09	3	35.09	
108	0300	1/27	22°29'	153°06'	73.6	12	17	74.5	69.5	1019	02	4,8	2	9	3	12	4	35.09	
109	0600	1/27	22°00'	153°12'	74.0	11	15	73.2	68.4	1020	02	8	2	9	3	12	4	34.98	0.36
110	0900	1/27	21°46'	153°19'	74.0	12	13	74.1	69.2	1019	02	6	5	9	3	12	4	34.96	
111	1200	1/27	21°27'	153°37'	74.9	10	19	74.9	68.7	1018	02	4,6,8	4	9	4	12	4	34.67	
112	1500	1/27	21°08'	153°56'	75.0	11	20	75.0	69.0	1017	02	6	7	9	3	12	4	34.60	
113	1800	1/27	20°48'	154°15'	74.1	13	17	76.5	69.4	1019	02	4,8	2	9	3	12	4	34.84	
114	2100	1/27	20°28'	154°34'	75.4	12	20	75.8	69.4	1018	02	4	1	9	4	12	4	34.67	
115	0000	1/28	20°05'	154°51'	76.1	13	14	76.8	70.1	1015	03	4,6	4	9	3	12	4	34.50	
116	0000	1/29	18°39'	155°49'	77.5	07	18	77.0	71.5	1015	02	8	1	9	3	12	4	34.27	
117	0300	1/29	18°22'	156°12'	77.1	09	15	76.9	71.4	1015	02	8	1	9	3	10	4	34.43	
118	0600	1/29	18°03'	156°35'	77.3	10	18	76.7	71.6	1017	02	8	1	9	3	10	4	34.33	
119	0900	1/29	17°48'	156°50'	77.3	09	19	76.7	71.9	1016	02	8	2	9	3	10	4	34.36	
120	1200	1/29	17°31'	157°14'	77.5	09	19	76.7	71.0	1016	02	8	3	9	3	09	4	34.35	

Table 2.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 50 (con.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Barometer (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO4-P, (ug. at./l.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T.)	Amt.		
121	1500	1/29	17°14'	157°37'	77.5	07	18	76.6	71.9	1015	03	8,6	6	9	3	07	4	34.27	
122	1800	1/29	16°54'	158°02'	78.0	08	21	77.2	72.0	1017	02	8	5	9	3	08	4	34.20	
123	2100	1/29	17°12'	158°19'	78.1	09	18	77.9	72.1	1017	02	8	5	9	3	08	4	34.19	
124	0000	1/30	17°31'	158°42'	77.6	09	18	77.2	71.3	1014	02	8	4	9	3	08	4	34.18	
125	0300	1/30	17°51'	159°06'	77.7	08	16	78.0	72.5	1014	02	8	2	9	3	08	4	34.25	
126	0600	1/30	18°10'	159°29'	77.4	08	14	76.9	71.6	1016	02	8	3	9	3	08	4	34.23	
127	0900	1/30	18°26'	159°45'	75.6	06	09	75.8	70.3	1018	02	8	3	9	2	08	4	34.82	
128	1200	1/30	18°44'	160°07'	75.6	06	10	75.0	70.5	1017	02	8	1	9	2	11	4	34.94	
129	1500	1/30	19°03'	160°28'	75.6	05	07	74.9	70.1	1016	02	X	0	9	2	11	4	34.87	
130	1800	1/30	19°19'	160°49'	75.5	05	06	74.9	69.5	1018	02	4,8	3	9	1	11	1	34.94	
131	2100	1/30	19°35'	161°14'	75.6	10	04	76.5	70.3	1019	01	8	1	9	1	11	2	34.86	
132	0000	1/31	19°50'	161°35'	77.4	03	06	76.5	69.4	1016	02	8	1	9	1	11	2	34.98	
133	0300	1/31	20°07'	161°53'	77.7	00	06	75.8	68.2	1016	02	8	1	9	1	11	2	34.92	
134	0600	1/31	20°26'	162°12'	76.1	01	12	76.7	69.0	1018	02	8	3	9	1	11	2	34.92	
135	0900	1/31	20°42'	162°29'	76.1	00	10	75.0	68.5	1018	02	X	2	9	2	11	2	34.95	
136	1200	1/31	21°01'	162°32'	75.4	03	22	73.0	68.8	1018	03	X	6	9	3	11	2	34.89	
137	1500	1/31	21°20'	162°34'	75.4	02	22	71.9	65.9	1018	02	X	6	9	3	02	4	34.92	
138	1900	1/31	21°42'	162°38'	74.8	04	22	70.0	60.7	1022	02	6,8	6	9	4	00	3	34.98	
139	0000	2/1	22°05'	162°43'	75.0	05	23	70.0	62.5	1020	02	6	7	9	4	03	3	34.91	
140	0600	2/1	22°35'	162°45'	73.8	06	27	69.0	60.8	1023	02	X	7	9	4	03	3	35.06	0.29
141	0900	2/1	22°16'	163°04'	74.4	07	20	68.9	62.3	1024	66	X	8	X	4	03	3	34.99	
142	1200	2/1	21°55'	163°23'	74.9	07	26	69.1	64.2	1023	01	X	2	7	4	07	4	35.00	
143	1500	2/1	21°34'	163°43'	74.0	06	25	70.3	64.0	1021	02	6,8	4	9	4	06	3	35.03	
144	1800	2/1	21°14'	164°02'	74.5	06	25	68.5	64.9	1022	15	6,8	6	9	4	07	3	34.99	
145	2100	2/1	20°56'	164°21'	75.0	08	26	75.9	65.1	1023	01	4,8	4	9	4	07	3	34.92	
146	0000	2/2	20°37'	164°40'	75.4	08	20	72.1	66.8	1020	02	6,8	4	9	4	07	3	34.93	
147	0300	2/2	20°16'	164°59'	74.9	08	22	73.0	66.7	1019	02	6,8	3	9	4	08	3	34.98	
148	0600	2/2	19°54'	165°19'	75.5	09	23	73.1	67.9	1019	02	6	3	9	3	08	3	34.85	
149	0900	2/2	19°32'	165°21'	75.7	09	18	74.2	69.0	1020	02	X	3	9	3	08	3	34.84	
150	1200	2/2	19°03'	165°26'	75.0	08	16	74.5	68.0	1019	02	X	2	9	3	08	3	34.93	
151	1450	2/2	18°35'	165°32'	76.4	06	20	75.1	67.5	1017	03	X	7	9	3	08	3	34.75	
152	2255	2/2	18°46'	165°49'	75.4	06	18	74.7	68.7	1018	02	6,8	6	9	3	08	3	34.93	
153	0600	2/3	18°14'	166°00'	74.9	07	16	75.2	66.0	1017	02	6	7	9	3	08	3	34.98	
154	0900	2/3	17°54'	166°03'	76.8	08	23	74.5	69.8	1017	02	X	7	9	3	08	3	34.56	
155	1200	2/3	17°28'	166°08'	77.3	09	23	75.4	66.9	1016	02	X	8	X	3	08	3	34.59	
156	1500	2/3	17°02'	166°14'	77.5	07	20	76.0	67.6	1015	02	X	8	7	3	08	3	34.54	
157	1800	2/3	16°35'	166°20'	77.6	07	20	76.5	66.8	1016	02	6,8	7	8	3	08	3	34.42	
158	2100	2/3	16°24'	166°41'	77.9	07	19	77.9	68.0	1017	02	6	7	9	3	07	3	34.39	
159	0000	2/4	16°25'	167°11'	77.6	08	22	77.4	67.5	1015	01	6,8	2	9	3	07	3	34.27	
160	0300	2/4	16°25'	167°42'	77.4	08	17	77.0	69.5	1014	02	6,8	4	9	3	07	3	34.28	

Table 2.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 50 (con.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Barometer (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO_4-P, (ug. at./l.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T.)	Amt.		
161	0600	2/4	16°24'	168°14'	77.5	08	21	76.8	69.0	1014	02	6,8	2	9	3	07	3	34.33	
162	0900	2/4	16°25'	168°37'	76.0	08	14	75.7	70.8	1015	02	X	3	9	3	07	3	34.83	
163	1200	2/4	16°25'	169°08'	76.2	08	22	76.0	69.0	1014	02	X	2	9	4	07	4	34.83	
164	1500	2/4	16°25'	169°39'	76.4	08	26	74.8	69.7	1012	02	6,8	2	9	4	07	4	34.92	
165	2015	2/4	16°24'	170°02'	76.4	08	20	75.7	69.5	1014	02	6,8	2	9	4	07	4	34.85	
166	0000	2/5	16°22'	170°41'	76.8	07	23	76.1	69.3	1012	02	6,8	4	9	4	06	4	34.85	
167	0300	2/5	16°10'	170°22'	76.9	06	19	75.9	69.2	1012	02	4,6,8	5	9	4	06	4	34.71	
168	0600	2/5	15°57'	170°01'	76.6	07	16	75.0	69.0	1011	02	6,8	4	9	4	06	4	34.83	
169	0900	2/5	15°46'	169°44'	77.0	08	16	74.8	69.5	1012	02	X	4	9	4	06	4	34.52	
170	1200	2/5	15°32'	169°23'	77.1	08	16	76.0	69.6	1011	02	X	3	9	4	06	4	34.40	
171	1500	2/5	15°17'	169°03'	77.5	08	16	76.3	69.2	1009	02	X	2	9	4	06	4	34.37	
172	1800	2/5	15°02'	168°42'	77.4	09	14	76.5	69.2	1010	14	4,6,8	3	9	3	08	3	34.28	
173	2100	2/5	14°52'	168°23'	77.5	10	20	75.1	70.6	1012	16	6,8	6	9	3	08	3	34.27	
174	0000	2/6	14°40'	168°01'	77.9	08	19	76.5	71.2	1010	02	6,8	4	9	3	08	3	34.33	
175	0300	2/6	14°29'	167°38'	78.0	08	22	76.8	71.0	1008	02	6,8	5	9	3	08	3	34.41	
176	0600	2/6	14°18'	167°16'	78.0	07	20	77.0	71.9	1009	02	6,8	4	9	3	08	3	34.34	
177	0900	2/6	14°10'	166°57'	78.1	07	20	77.4	72.0	1009	02	X	4	9	3	08	3	34.27	
178	1200	2/6	13°59'	166°35'	78.0	07	20	76.0	72.8	1010	14	X	6	7	4	08	4	34.22	
179	1500	2/6	13°48'	166°13'	78.0	07	22	76.7	72.9	1008	02	X	4	9	3	08	3	34.24	
180	1800	2/6	13°37'	165°52'	78.2	06	20	77.5	72.8	1010	15	4,6	7	9	3	08	3	34.17	
181	2100	2/6	13°20'	165°37'	78.5	06	22	78.0	74.0	1010	02	6,8	7	8	3	08	3	34.10	
182	0000	2/7	13°05'	165°21'	78.6	06	20	78.6	74.0	1008	02	6,8	8	8	3	08	3	34.32	
183	0300	2/7	13°19'	165°10'	78.6	06	22	78.0	73.9	1007	15	6,8	8	8	3	08	3	34.28	
184	0600	2/7	13°33'	164°58'	78.5	05	22	77.1	73.8	1008	14	X	8	8	3	06	3	34.25	
185	1000	2/7	13°51'	164°45'	78.8	06	20	78.0	74.2	1010	02	X	8	8	3	06	3	34.22	
186	1400	2/7	14°10'	164°31'	78.2	06	23	78.3	73.6	1008	02	X	X	X	3	06	3	34.21	
187	1800	2/7	14°29'	164°16'	78.1	06	21	77.5	73.5	1009	02	6,8	7	8	3	06	3	34.19	
188	2200	2/7	14°50'	164°02'	77.8	06	21	78.0	73.7	1010	02	6,8	7	8	3	06	3	34.27	
189	0200	2/8	15°10'	163°42'	77.4	06	20	77.0	73.8	1008	02	6,8	7	8	3	06	3	34.41	
190	0600	2/8	15°29'	163°20'	76.9	06	22	76.0	73.2	1009	14	6,8	7	9	3	06	3	34.73	0.26
191	1000	2/8	15°46'	162°59'	76.9	06	16	76.2	73.9	1010	14	X	8	7	3	06	3	34.72	
192	1400	2/8	16°08'	162°33'	76.4	06	14	76.5	74.0	1008	02	X	8	8	2	06	3	34.75	
193	1800	2/8	16°31'	162°09'	76.3	06	13	76.0	72.9	1010	14	6	8	8	2	06	3	34.45	
194	2100	2/8	16°51'	161°50'	77.2	08	11	77.5	74.8	1011	15	6,8	8	8	2	07	3	34.33	
195	0000	2/9	17°10'	161°34'	76.5	09	09	76.8	74.5	1010	14	0	8	5	2	09	3	34.33	
196	0325	2/9	17°31'	161°20'	76.6	10	16	77.5	74.3	1010	60	0	8	5	2	09	3	34.29	
197	0600	2/9	17°49'	161°04'	76.7	11	17	75.5	71.9	1011	14	0	7	5	2	09	3	34.28	
198	0900	2/9	18°06'	160°48'	76.5	12	20	77.5	73.9	1010	02	X	8	7	2	09	3	34.35	0.31
199	1200	2/9	18°29'	160°30'	75.0	13	18	77.0	73.9	1011	14	X	8	7	3	09	3	34.75	
200	1500	2/9	18°52'	160°13'	75.2	13	11	76.4	73.7	1011	02	X	8	X	2	09	3	34.77	

Table 2.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 50 (con.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Barometer (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO_4-P, (ug. at./l.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T.)	Amt.		
201	2300	2/9	19°10'	160°05'	75.2	10	14	76.5	73.5	1012	20	0,6	8	7	2	10	1	34.84	0.36
202	0600	2/10	19°40'	159°31'	76.2	11	10	74.6	71.0	1014	61	X	8	5	2	10	1	34.34	
203	0900	2/10	19°58'	159°13'	76.0	14	08	74.4	71.3	1014	20	X	8	X	2	10	1	34.53	
204	1200	2/10	20°20'	158°53'	76.1	14	08	74.1	71.1	1013	60	X	8	X	2	10	1	34.32	
205	1500	2/10	20°43'	158°33'	75.4	17	02	74.0	70.9	1012	60	X	8	X	2	X	1	34.46	

Table 3.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 51
(Recording and coding of data follows U.S. Navy Hydrographic Office, 1956.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Barometer (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO4-P, (ug. at./l.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T.)	Amt.		
1	0020	3/6	21°17.5'	156°21.5'	74.8	08	20	75.7	68.3	1019	00	8	4	7	4	07	3	34.65	
2	0600	3/6	21°48'	156°12'	74.7	08	20	73.2	67.3	1021	00	8	6	7	4	XX	X	34.56	
3	1200	3/6	22°15.5'	155°54.8'	72.8	06	24	72.0	66.8	1022	00	X1/	5	7	5	06	3	34.98	
4	1800	3/6	22°44.8'	155°35'	73.2	08	20	71.8	64.1	1023	00	8	6	7	4	06	3	35.02	
5	0000	3/7	23°22.3'	155°17.5'	72.8	08	23	74.0	65.6	1022	01	8	2	7	4	07	3	35.00	
6	0300	3/7	23°41.5'	155°11'	72.8	09	22	72.8	65.0	1021	02	8	2	7	4	06	3	34.97	
7	0600	3/7	23°55.3'	155°01.5'	72.7	08	18	72.3	65.5	1024	00	8	3	7	4	06	3	34.96	
8	1000	3/7	23°57.5'	154°42.8'	72.3	09	16	71.9	64.7	1024	00	8	2	7	4	06	3	34.95	
9	1400	3/7	23°56.2'	154°22'	72.1	10	20	71.0	64.2	1022	01	X	0	7	4	08	3	35.04	
10	1800	3/7	23°56'	154°02.5'	71.3	10	20	71.9	61.6	1023	02	8	6	7	4	08	3	35.19	
11	0000	3/8	23°57'	153°31'	70.9	09	18	72.0	65.3	1021	02	8	6	7	4	08	3	35.21	0.07
12	0500	3/8	23°56.2'	152°56'	70.3	09	18	71.4	64.0	1022	02	8	5	7	4	08	3	35.24	
13	0900	3/8	23°55.8'	152°35'	70.4	09	23	72.3	63.5	1023	00	X	X	7	4	08	3	35.24	
14	1300	3/8	23°55.5'	152°13'	70.2	09	20	69.5	64.5	1022	00	X	6	7	4	08	3	35.22	
15	1700	3/8	23°55.8'	151°53'	70.8	10	16	71.6	61.9	1022	15	6	7	7	4	08	3	35.16	
16	2100	3/8	23°57'	151°32.3'	71.5	09	16	71.3	64.1	1024	02	6	7	7	4	08	3	35.07	
17	0100	3/9	23°57.8'	151°13.2'	71.2	10	21	69.7	64.0	1022	02	8	8	7	4	08	3	35.08	
18	0500	3/9	23°58.2'	150°53'	71.0	10	20	71.2	64.0	1022	02	8	8	7	4	08	3	35.08	
19	0900	3/9	23°58.5'	150°31.5'	70.8	10	21	72.0	64.3	1023	00	X	6	7	4	08	3	35.17	
20	1300	3/9	23°59.2'	150°10'	70.9	10	24	71.0	62.3	1021	00	8	8	7	5	08	3	35.11	
21	1700	3/9	24°01'	149°49.5'	71.3	10	22	70.9	64.0	1023	00	6	7	7	5	08	3	35.05	
22	2100	3/9	24°05'	149°32'	71.2	10	19	72.7	64.5	1024	02	6	7	7	5	08	3	35.09	0.18
23	0100	3/10	24°03.5'	149°08'	72.5	09	18	72.2	66.0	1021	01	8	3	7	5	08	3	34.89	
24	0500	3/10	24°01.5'	148°41'	71.8	09	20	70.9	65.0	1023	03	8	6	7	5	08	3	34.96	
25	0900	3/10	24°01'	148°20'	71.6	09	13	70.3	64.0	1025	02	X	4	7	5	08	3	35.05	
26	1300	3/10	24°00'	147°57'	70.5	09	20	70.6	62.5	1022	01	8	2	7	5	08	3	35.03	
27	1700	3/10	23°59.5'	147°36.5'	71.7	08	23	70.6	62.0	1022	15	4	5	7	5	08	3	34.99	
28	2100	3/10	23°59.5'	147°20'	71.7	09	21	70.7	62.1	1023	02	8	6	7	5	08	3	35.04	
29	0100	3/11	23°57.8'	146°59'	71.1	09	23	70.9	63.0	1020	02	8	6	7	5	08	6	35.09	
30	0500	3/11	23°56.5'	146°37.8'	71.3	09	23	70.5	63.6	1021	02	8	4	7	5	08	6	35.07	
31	0900	3/11	23°55.2'	146°17'	70.3	09	18	70.1	62.8	1022	00	X	4	7	5	08	3	35.09	
32	1300	3/11	23°54'	145°56.5'	70.5	09	23	69.7	62.4	1021	01	8	2	7	5	08	6	35.15	
33	1700	3/11	23°53'	145°31.5'	70.5	08	18	70.2	63.7	1022	15	0	8	7	4	07	3	35.16	
34	2100	3/11	23°52.5'	145°08'	70.0	08	23	70.8	63.7	1023	02	4	8	7	5	07	3	35.17	
35	0000	3/12	23°36'	145°09.5'	70.1	06	28	70.1	64.7	1021	02	8	8	7	5	06	6	35.16	
36	0300	3/12	23°09.7'	145°25'	70.5	06	32	70.5	65.9	1020	02	8	8	7	5	06	6	35.17	
37	0600	3/12	22°46.5'	145°37'	71.8	07	26	70.7	64.5	1022	02	X	6	7	5	06	6	35.03	
38	0900	3/12	22°26.2'	145°46'	71.9	07	26	71.0	66.3	1022	80	X	8	7	5	06	6	34.87	
39	1200	3/12	22°06'	145°55.2'	72.5	07	26	72.0	67.0	1020	01	8	2	7	5	06	6	34.88	
40	1500	3/12	21°45.3'	146°05'	72.0	07	25	71.6	67.0	1019	02	8	8	7	5	06	6	34.94	

1/ X indicates that no observation was recorded.

Table 3.--Summary of observations at bathythermograph lowerings, *Hugh M. Smith* cruise 51 (con.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Barometer (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO_4-P, (ug. at./l.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T.)	Amt.		
41	1800	3/12	21°24.5'	146°14.2'	72.4	07	23	72.0	67.4	1020	02	8	6	7	5	06	6	34.94	
42	2100	3/12	21°05'	146°23.3'	72.3	07	22	72.1	68.1	1020	25	6	6	7	5	07	6	35.06	
43	0000	3/13	20°44'	146°32'	73.0	07	24	71.9	68.8	1019	50	8	7	7	5	06	6	34.91	
44	0300	3/13	20°20.2'	146°41'	73.0	07	19	72.9	69.2	1017	02	8	8	7	4	06	3	34.89	
45	0600	3/13	19°52.2'	146°51.8'	73.0	08	22	72.9	69.1	1018	80	8	8	6	4	06	3	34.89	
46	0900	3/13	19°30.6'	146°58.2'	73.0	08	24	73.1	69.5	1021	00	8	2	7	4	06	3	34.96	
47	1200	3/13	19°01.5'	147°10'	73.1	09	15	71.9	70.2	1016	51	8	8	6	3	06	3	34.89	
48	1500	3/13	18°33'	147°21'	75.0	09	16	75.0	71.8	1015	01	8	2	7	3	06	3	34.49	0.17
49	1700	3/13	18°19.5'	147°29.2'	75.0	09	18	74.1	69.8	1015	25	1	6	7	4	07	3	34.46	0.23
50	2235	3/13	18°21'	147°34.5'	75.1	09	12	76.3	71.1	1014	02	8	2	7	3	08	3	34.46	
51	0100	3/14	18°27'	147°30.5'	75.6	09	12	77.4	71.6	1012	03	8	5	7	3	08	3	34.50	
52	0600	3/14	17°45.2.	147°42'	74.9	11	10	76.2	71.2	1014	02	8	2	7	2	XX	1	34.53	
53	0900	3/14	17°23'	147°51'	75.2	12	06	75.7	70.8	1016	13	x	1	8	2	00	0	34.53	
54	1200	3/14	16°56'	148°04.2'	75.2	10	05	75.0	71.0	1014	02	8	1	8	2	08	1	34.45	
55	1500	3/14	16°28.5'	148°17.2'	75.2	17	06	75.0	70.9	1013	03	8	3	8	2	08	1	34.54	
56	1800	3/14	16°04'	148°28.5'	75.4	13	06	77.1	71.4	1015	02	4	2	8	2	06	1	34.47	
57	2100	3/14	15°34.2'	148°34.5'	77.2	17	02	79.5	72.0	1015	02	4	1	8	1	08	4	34.45	
58	0000	3/15	15°14.2'	148°43'	78.0	07	06	77.5	71.7	1013	03	4	6	8	2	07	1	34.40	
59	0300	3/15	14°45.3'	148°54'	77.0	11	06	77.2	72.0	1013	03	8	8	7	2	06	1	34.34	
60	0600	3/15	14°21.2'	149°05.5'	77.0	05	06	77.9	72.8	1015	02	8	6	7	2	06	1	34.21	
61	0900	3/15	14°01'	149°17'	76.7	09	10	77.5	73.0	1015	02	8	8	6	2	06	1	34.30	
62	1200	3/15	14°19.2'	149°39'	76.9	04	10	76.9	72.0	1014	01	8	2	7	2	08	1	34.29	
63	1500	3/15	14°40'	150°02'	76.9	06	13	76.5	72.5	1014	02	8	2	7	2	07	1	34.38	
64	1710	3/15	14°44'	150°14.5'	76.9	06	15	76.8	72.0	1016	02	8	2	7	2	03	1	34.46	0.31
65	2210	3/15	14°44.5'	150°13'	77.2	06	06	78.5	72.7	1016	02	4	2	8	2	06	1	34.42	
66	0030	3/16	14°49.5'	150°14.5'	77.1	05	16	79.4	72.9	1014	02	4	2	8	2	06	1	34.42	
67	0300	3/16	15°02.7'	150°28.2'	76.9	06	14	78.7	72.1	1015	02	4	2	8	2	06	1	34.34	
68	0600	3/16	15°21'	150°48.5'	76.8	06	15	77.7	72.4	1018	02	4	1	8	2	06	1	34.17	
69	0900	3/16	15°39'	151°03.5'	76.5	06	15	76.8	72.2	1019	00	4	4	8	2	06	1	34.25	
70	1200	3/16	16°00'	151°25'	76.1	06	15	76.0	71.8	1018	01	8	2	8	2	06	1	34.44	
71	1500	3/16	16°22.8'	151°47'	76.3	06	15	75.6	71.3	1018	02	8	2	8	2	06	1	34.23	
72	1800	3/16	16°45'	152°05.5'	76.3	04	16	77.1	71.0	1020	02	8	2	8	2	03	1	34.44	
73	2100	3/16	17°07'	152°22'	76.0	04	17	78.2	72.1	1021	02	8	2	8	3	02	1	34.34	
74	0000	3/17	17°29.5'	152°40'	76.0	04	18	77.4	71.3	1018	03	8	4	8	3	03	3	34.35	
75	0300	3/17	17°52.3	152°57'	76.0	05	22	76.4	71.2	1018	02	8	3	8	3	03	3	34.42	
76	0600	3/17	18°15.7'	153°13.5'	75.1	05	21	75.2	70.0	1020	02	8	2	8	3	03	3	34.51	
77	0900	3/17	18°34.8'	153°26'	74.5	05	19	75.2	69.2	1022	02	8	1	8	3	03	3	34.65	
78	1200	3/17	19°01.5'	153°30'	74.9	05	17	74.5	69.4	1021	03	8	2	8	3	03	3	34.57	
79	1500	3/17	19°27.5'	153°33.5'	74.0	05	17	73.7	69.0	1021	02	8	2	8	3	03	3	34.66	
80	1800	3/17	19°53.2'	153°36.5'	73.9	06	18	74.3	69.0	1023	02	8	3	8	3	03	3	34.66	

Table 3.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 51 (con.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.).	Wind		Air temp.		Barometer (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO_4-P, (ug. at./l.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T.)	Amt.		
81	2100	3/17	20°19'	153°40.5'	74.4	06	17	76.3	69.3	1022	02	8	2	8	2	03	3	34.60	0.18
82	0000	3/18	20°45'	153°43.5'	74.5	04	14	74.5	67.8	1022	02	8	2	8	2	03	3	34.65	
83	0300	3/18	21°11'	153°47.5'	73.9	04	15	75.8	68.8	1021	02	8	2	8	2	03	3	34.81	0.19
84	0600	3/18	21°36'	153°50.6'	73.4	05	20	74.0	69.1	1022	02	8	5	7	3	03	3	34.81	
85	0900	3/18	21°57'	153°52.8'	71.3	06	19	74.0	70.1	1023	02	8	2	7	3	03	3	35.21	
86	1200	3/18	22°22.8'	153°56.5'	72.6	05	16	73.5	70.0	1023	02	8	5	7	3	03	3	34.98	
87	1500	3/18	22°48'	154°01'	71.8	06	15	72.0	69.0	1022	01	8	1	8	3	03	3	35.16	
88	1800	3/18	22°53.5'	154°18'	72.7	05	13	73.8	69.6	1023	02	8	6	8	2	04	3	35.00	
89	2100	3/18	22°40'	154°48.8'	72.9	06	13	74.9	70.2	1023	02	8	4	8	3	03	3	34.94	
90	0000	3/19	22°33'	155°02.3'	75.2	07	09	76.0	70.7	1021	02	8	5	8	2	07	1	34.64	
91	0300	3/19	22°15.5'	155°23.5'	74.3	04	12	76.9	70.7	1021	01	8	2	8	2	07	1	34.70	
92	0600	3/19	22°02.8'	155°53'	74.9	06	17	75.0	69.6	1022	02	8	2	8	2	07	1	34.60	
93	0900	3/19	21°53.2'	156°15.8'	74.7	06	19	74.7	70.0	1022	25	8	6	8	2	07	1	34.63	
94	1200	3/19	21°43'	156°45'	74.0	08	19	74.1	70.1	1021	01	8	2	8	2	07	1	34.74	
95	1500	3/19	21°31.2'	157°15.5'	74.0	08	19	73.8	69.1	1021	03	8	5	8	2	07	1	34.71	
96	0000	3/22	21°20.5'	158°20.8'	75.6	10	13	79.5	69.5	1020	02	8	1	8	2	07	1	34.65	
97	0300	3/22	21°31.5'	158°49'	75.0	08	20	75.8	69.0	1021	02	8	1	8	3	07	1	34.65	
98	0600	3/22	21°42.8'	159°18.5'	75.8	06	22	76.3	70.0	1022	00	8	5	8	3	07	1	34.46	
99	0900	3/22	21°53'	159°39'	75.1	08	16	76.0	69.2	1023	00	8	5	7	2	07	1	34.44	
100	1200	3/22	22°07'	160°09'	75.0	06	19	75.0	70.0	1021	02	5	4	8	3	06	1	34.55	
101	1500	3/22	22°20'	160°39'	73.9	08	18	73.6	69.8	1019	01	8,5	2	8	3	06	1	34.81	
102	1800	3/22	22°35.5'	161°04.7'	74.0	08	17	75.4	69.8	1021	00	8	5	8	3	05	1	34.72	
103	2110	3/22	22°55'	161°30'	74.3	09	16	75.7	69.0	1021	01	8	2	8	3	06	1	34.81	
104	0000	3/23	22°52'	161°46'	74.2	13	15	76.0	69.5	1019	02	8	2	8	3	12	1	34.87	
105	0300	3/23	22°32'	161°38'	74.5	16	06	75.2	68.3	1018	02	8	1	8	2	13	1	34.64	
106	0600	3/23	22°08.5'	161°30'	74.2	16	06	75.2	68.6	1019	02	8	1	8	2	12	1	34.74	
107	0900	3/23	21°44.5'	161°21.5'	74.1	12	04	75.5	69.4	1020	03	8	2	8	3	12	1	34.84	
108	1200	3/23	21°15'	161°14.5'	75.8	16	07	75.0	69.0	1018	00	X	0	8	2	12	1	34.24	
109	1500	3/23	20°45.7'	161°07.2'	75.7	14	05	74.7	69.9	1018	02	X	0	8	2	11	1	34.52	
110	1040	3/23	20°28.5'	161°07.3'	75.3	09	12	75.5	70.2	1019	03	6	6	8	2	06	1	34.60	
111	2310	3/23	20°29.4'	161°08'	75.8	09	12	77.9	71.5	1019	02	5	2	8	2	06	1	34.62	
112	0120	3/24	20°30'	161°03'	76.1	06	11	78.3	71.5	1018	15	8	6	7	2	06	1	34.51	
113	0330	3/24	20°21'	161°00'	76.0	09	11	77.0	70.9	1018	02	8,4	7	7	2	11	1	34.51	
114	0600	3/24	19°58'	160°51.5'	76.5	11	11	76.4	70.3	1019	01	8	1	7	2	12	1	34.27	
115	0900	3/24	19°36.2'	160°44.5'	76.8	13	10	77.3	69.9	1021	02	X	0	7	3	12	1	34.23	
116	1200	3/24	19°09.8'	160°37.8'	76.6	11	10	76.2	70.6	1020	02	X	0	7	3	11	3	34.06	
117	1500	3/24	18°43.7'	160°31.2'	76.8	10	13	76.2	69.4	1019	03	8	1	7	3	11	3	33.96	
118	1800	3/24	18°17.8'	160°24'	76.9	09	18	76.4	71.5	1020	15	8	5	7	3	11	3	34.14	
119	2100	3/24	17°51'	160°16.8'	76.9	10	19	78.2	69.4	1021	01	4	1	7	3	11	3	34.15	0.20
120	0000	3/25	18°10	159°54.5'	77.0	09	19	77.9	70.0	1019	02	4,8	6	7	3	09	3	34.15	

Table 3.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 51 (con.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind Dir. (°T.)	Wind Force (kn.)	Air temp. Dry bulb (°F.)	Air temp. Wet bulb (°F.)	Barometer (mb.)	Weather	Clouds Type	Clouds Cover	Visibility	Sea	Swell Dir. (°T.)	Swell Amt.	Surf. sal. (‰)	Surf. PO4-P, (ug. at./l.)
121	0300	3/25	18°28'	159°33.0'	76.2	07	21	79.1	71.5	1019	02	8	6	7	3	08	3	34.36	
122	0600	3/25	18°48'	159°11'	76.1	07	14	77.1	70.3	1020	02	8	2	7	3	09	3	34.40	
123	0900	3/25	19°04'	158°50'	76.0	12	26	76.7	69.9	1021	02	8	1	7	3	09	3	34.43	
124	1200	3/25	19°23.2'	158°28.5'	76.1	09	16	75.8	71.0	1020	03	8	4	7	3	09	3	34.16	
125	1500	3/25	19°42'	158°08'	76.0	10	10	75.8	70.5	1019	03	8	7	7	3	09	3	34.23	
126	1800	3/25	19°57'	157°44.2'	75.1	07	17	74.9	70.6	1021	80	0	6	7	5	07	3	34.64	
127	2100	3/25	20°05.5'	157°29.2'	74.8	08	19	77.6	71.5	1022	02	8	1	7	5	07	3	34.68	
128	0300	3/26	20°31'	157°04.5'	75.2	09	22	77.6	71.0	1018	02	8	2	8	4	08	3	34.49	
129	0900	3/26	21°09'	156°30.5'	74.1	09	24	75.2	70.0	1022	02	8	4	7	4	08	3	34.63	
130	1500	3/26	21°24.2'	156°03.8'	73.4	11	23	74.1	70.0	1018	03	8	7	6	4	09	3	34.55	
131	2000	3/26	21°44.3'	155°36.8	74.5	10	24	75.3	70.7	1024	14	8	3	7	4	08	3	34.63	
132	0000	3/27	22°05.2'	155°12.5'	74.8	11	26	77.0	70.2	1022	03	8	7	7	4	10	6	34.49	
133	0400	3/27	22°22.2'	154°48.2'	74.5	10	25	75.5	69.9	1022	01	8	5	7	4	09	6	34.63	
134	0800	3/27	22°41.2'	154°24.8'	74.0	10	23	74.9	69.5	1024	02	8	5	7	4	09	6	34.66	
135	1200	3/27	22°57'	153°56'	72.0	10	20	73.8	67.0	1024	02	8	7	7	4	09	6	35.00	
136	1600	3/27	23°12.5'	153°26.5'	72.7	11	24	72.2	65.9	1024	14	6	7	7	3	09	3	34.95	
137	2000	3/27	23°28'	152°56.2'	72.1	10	18	75.4	67.4	1026	02	6	7	7	3	08	3	35.08	
138	0000	3/28	23°44.5'	152°24'	72.6	12	22	75.2	66.5	1025	01	8	1	7	3	09	3	34.95	
139	0400	3/28	24°01.7'	151°50.5'	72.5	11	18	74.5	66.8	1024	02	8	1	7	3	09	3	35.01	
140	0800	3/28	24°13'	151°21.2'	73.0	09	16	73.3	66.8	1027	02	8	2	7	3	09	3	34.77	
141	1200	3/28	24°11'	150°51'	72.9	10	20	70.5	67.0	1025	03	8	6	7	3	09	3	34.73	
142	1600	3/28	24°09.2'	150°16.8'	71.7	08	22	70.8	66.8	1024	15	8	3	7	3	09	3	35.09	
143	2000	3/28	24°09.8'	149°47.5'	72.1	11	19	72.3	62.6	1025	02	8	2	7	3	09	3	34.93	
144	0000	3/29	24°08.5'	149°21.8'	72.0	11	21	72.1	64.3	1023	01	8	1	7	4	10	3	34.97	
145	0400	3/29	24°05.5'	148°57.8'	71.8	10	20	72.5	65.0	1024	03	8	3	7	4	10	3	35.04	
146	0800	3/29	24°02'	148°35'	71.7	09	20	72.5	63.8	1026	01	8	2	7	4	10	3	35.06	
147	1200	3/29	23°57.5'	148°09.5'	71.9	10	23	71.6	64.5	1024	02	8	6	7	4	10	3	34.96	
148	1615	3/29	23°53.8'	147°43.5'	71.4	10	24	71.3	61.5	1025	15	6	7	7	4	08	4	35.04	
149	2000	3/29	23°31'	147°28'	71.4	10	22	72.5	63.2	1025	15	6	7	7	4	09	3	35.06	
150	0000	3/30	23°03'	147°11'	71.4	08	20	71.0	65.5	1023	21	8	6	7	4	09	6	35.06	
151	0400	3/30	22°36.5'	146°53'	72.4	11	20	71.9	66.2	1021	01	8	5	7	4	10	6	34.97	
152	0800	3/30	22°21.5'	146°35.3'	72.2	09	24	72.4	66.9	1023	00	8	6	7	4	10	3	34.76	
153	1200	3/30	22°07.2'	146°18.5'	72.2	10	22	71.9	65.0	1021	00	8,4	6	7	4	10	6	34.65	
154	1600	3/30	21°53'	146°02'	72.3	09	25	72.4	65.3	1022	15	6	6	7	4	09	6	34.91	
155	2000	3/30	21°32.7'	145°46'	72.7	10	19	72.3	66.4	1023	15	8,4	6	7	4	09	3	34.83	
156	0000	3/31	21°04'	145°30.8'	72.9	10	20	72.8	64.9	1020	02	8,4	6	7	4	10	6	34.82	
157	0400	3/31	20°35.5'	145°16'	72.8	10	20	72.0	65.5	1020	02	8	7	7	4	10	6	34.82	
158	0830	3/31	20°05'	145°38.7'	72.9	09	17	72.3	66.5	1022	25	8	2	7	4	10	3	34.84	
159	1200	3/31	19°36'	146°03'	73.3	10	19	71.7	67.8	1019	02	8	6	7	4	10	6	34.77	
160	1500	3/31	19°11.2'	146°23.8'	73.6	08	19	71.8	67.3	1019	02	8	7	7	3	10	3	34.59	

Table 3.--Summary of observations at bathythermograph lowerings, Hugh M. Smith cruise 51 (con.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Baro-meter (mb.)	Wea-ther	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO_4-P, (ug. at./1.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T.)	Amt.		
161	1650	3/31	19°00'	146°36'	73.7	09	19	73.0	67.5	1019	15	6	7	7	3	07	3	34.69	
162	2225	3/31	19°00.5'	146°37'	73.8	10	20	74.8	69.0	1018	02	4,8	4	7	3	08	3	34.73	
163	0035	4/1	19°04'	146°34.5'	73.9	10	12	75.5	69.5	1018	02	8,4	4	7	3	10	3	34.67	
164	0300	4/1	18°48'	146°48'	74.3	08	13	75.0	69.8	1018	03	8,4	6	7	3	09	3	34.57	
165	0600	4/1	18°23.8'	147°08'	74.0	10	20	73.1	69.0	1018	00	8	2	7	3	09	3	34.60	
166	0900	4/1	18°03.8'	147°19.3'	74.5	09	12	74.2	69.8	1018	02	8	1	7	3	09	3	34.57	
167	1200	4/1	17°36'	147°38'	74.7	08	11	74.0	69.5	1017	02	8	1	7	3	09	3	34.48	
168	1500	4/1	17°09.2'	147°56'	74.6	08	13	74.1	69.9	1016	03	8	3	7	3	09	3	34.57	
169	1800	4/1	16°43'	148°14.2'	74.4	07	14	75.6	70.7	1018	02	8	3	7	3	08	3	34.64	
170	2100	4/1	16°17.5'	148°32.3'	75.2	06	18	76.7	71.8	1018	02	8	3	7	3	08	3	34.49	
171	0000	4/2	15°51.2'	148°51.2'	75.5	07	20	75.8	71.3	1015	02	8	3	7	3	08	3	34.49	
172	0300	4/2	15°25'	149°10'	75.9	06	17	76.1	71.5	1015	03	8	6	7	3	07	3	34.32	
173	0600	4/2	14°59'	149°27.5'	75.9	05	22	76.7	71.2	1015	02	8	2	7	3	07	3	34.24	
174	0900	4/2	15°18'	149°37.2'	75.7	06	25	74.7	71.4	1016	03	8	6	6	3	07	3	34.32	
175	1200	4/2	15°43'	149°51.8'	75.2	06	26	75.0	69.6	1014	01	8	2	7	4	07	3	34.49	
176	1500	4/2	16°07'	150°06.8'	75.3	06	24	74.4	69.6	1014	03	8	5	7	4	07	3	34.27	
177	1740	4/2	16°20.3'	150°19.2'	75.1	05	25	75.2	66.5	1017	02	4,8	2	7	6	05	3	34.55	
178	2210	4/2	16°25'	150°24.5'	75.7	06	17	77.0	69.7	1015	02	8	3	7	5	05	3	34.50	
179	0030	4/3	16°28'	150°26'	75.5	06	29	75.0	70.0	1014	15	8	6	7	4	06	6	34.53	
180	0300	4/3	16°45'	150°34'	75.6	06	24	77.0	70.5	1014	02	8	4	7	4	06	6	34.58	
181	0600	4/3	17°08.7'	150°48.3'	75.4	06	23	75.5	70.0	1016	80	8	2	7	4	06	6	34.57	
182	0900	4/3	17°31'	151°03.7'	75.2	07	23	73.7	69.7	1017	02	8	2	7	4	06	6	34.54	
183	1200	4/3	17°54'	151°18.2'	75.2	05	30	73.5	69.0	1016	03	8	3	7	5	06	6	34.48	
184	1500	4/3	18°17'	151°32.8'	74.1	05	30	72.3	66.0	1015	01	5	1	7	5	06	6	34.57	
185	1800	4/3	18°39.8	151°47'	74.0	04	27	72.4	67.0	1018	02	5	1	7	6	04	6	34.57	
186	2100	4/3	19°03'	152°01.2'	74.3	06	25	73.1	66.7	1019	02	6	1	7	6	04	6	34.65	
187	0000	4/4	19°29'	152°14.2'	74.7	06	23	74.5	66.4	1017	03	8,4	4	7	5	05	6	34.65	
188	0300	4/4	19°55'	152°27'	74.2	08	16	73.8	67.6	1017	03	8	7	7	4	04	6	34.56	
189	0600	4/4	20°21.2	152°40'	73.9	05	19	72.7	64.4	1019	02	8	2	7	4	04	6	34.64	
190	0900	4/4	20°47.5'	152°52'	74.0	05	24	70.8	65.4	1020	80	8	5	6	4	04	6	34.63	
191	1200	4/4	21°13'	153°04.5'	74.0	08	16	71.6	67.0	1018	01	8	2	7	4	05	6	34.68	
192	1500	4/4	21°38.2'	153°17'	74.0	09	23	70.0	66.0	1018	02	8	2	7	4	07	6	34.45	
193	1705	4/4	21°46.5'	153°27'	73.9	09	15	73.4	67.0	1019	15	8	2	7	4	07	3	34.77	
194	2215	4/4	21°46.2'	153°26.5'	74.4	09	09	72.7	66.7	1018	80	6,8	6	7	4	04	3	34.71	
195	0045	4/5	21°48'	153°23'	74.3	07	16	73.5	68.9	1016	15	8	5	7	4	04	3	34.65	
196	0300	4/5	22°05.5'	153°34.5'	74.2	09	16	73.4	67.7	1016	02	8	5	7	3	04	3	34.77	
197	0600	4/5	22°30'	153°51'	74.0	11	14	72.4	67.0	1018	18	8	6	7	3	04	3	34.73	
198	0900	4/5	22°53'	154°06'	71.6	09	12	70.6	67.4	1019	25	8	3	6	3	04	3	35.23	
199	1200	4/5	23°18.7'	154°22.2'	72.0	08	16	70.5	66.4	1018	01	8	2	7	3	05	3	35.14	
200	1500	4/5	23°44'	154°39'	71.5	10	14	70.6	67.2	1017	02	8	2	7	3	07	3	35.23	

Table 3.--Summary of observations at bathythermograph lowerings, *Hugh M. Smith* cruise 51 (con.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Barometer (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO_4-P, (ug. at./1.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T.)	Amt.		
201	1800	4/5	24°10'	154°52'	71.4	09	14	69.6	66.7	1018	18	0	6	7	3	05	3	35.23	
202	2100	4/5	23°48'	155°12.2'	73.0	14	14	72.8	68.5	1019	15	8	3	7	3	13	1	34.96	
203	0000	4/6	23°23'	155°33'	73.0	10	08	72.8	67.7	1016	02	8	2	7	2	08	1	35.10	
204	0300	4/6	22°59'	155°52.2'	74.1	14	13	73.9	67.5	1014	03	8	3	7	2	15	1	34.80	
205	0600	4/6	22°37'	156°13.5'	74.1	14	14	74.2	68.4	1014	00	8	1	7	2	15	1	34.72	
206	0900	4/6	22°22.2'	156°26.8'	73.7	15	08	74.5	67.9	1015	00	8	1	7	2	15	1	34.89	
207	1200	4/6	22°10'	156°45'	74.0	18	11	74.3	69.3	1014	03	8	2	7	2	15	1	34.80	
208	1500	4/6	21°54.5'	157°03'	74.0	26	14	74.0	68.0	1013	01	8	1	7	2	15	1	34.82	
209	1800	4/6	21°32.5'	157°27'	73.9	24	08	75.0	68.5	1016	02	8	1	8	2	17	1	34.80	

Table 4.--Summary of observations at bathythermograph lowerings, Charles H. Gilbert cruise 44
(Recording and coding of data follows U.S. Navy Hydrographic Office, 1956.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Barometer (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO4-P, (ug. at./1.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T.)	Amt.		
1	0020	5/1	21°48.0'	158°22.0'	76.0	09	18	78.2	71.4	1017	02	4	3	7	3	08	1	34.75	
2	0305	5/1	22°02.5'	158°24.0'	74.7	10	18	75.6	71.0	1016	01	1	4	7	3	08	1	35.01	
3	0605	5/1	22°31.0'	158°24.0'	74.1	11	18	74.1	69.6	1017	00	X[1]	9	7	3	08	1	35.02	
4	0905	5/1	22°49.0'	158°24.5'	74.1	07	13	74.0	69.5	1019	00	X	9	7	3	XX	X	34.98	
5	1200	5/1	23°15.0'	158°21.0'	74.2	12	13	74.0	69.9	1017	00	X	2	7	3	08	1	35.00	
6	1505	5/1	23°40.0'	158°18.5'	73.9	11	13	74.1	69.0	1016	00	8	2	7	3	08	1	35.43	
7	1800	5/1	24°06.0'	158°15.0'	73.4	12	16	75.1	69.5	1018	00	4	7	8	2	08	1	35.05	
8	2100	5/1	24°05.5'	158°43.0'	74.2	12	14	75.0	69.6	1019	02	2	6	8	2	09	1	34.97	
9	0000	5/2	24°05.5'	159°09.5'	75.0	12	13	75.3	69.8	1017	02	2	5	8	3	09	1	34.97	
10	0300	5/2	24°05.0'	159°37.0'	75.4	12	18	74.9	69.8	1016	03	8	6	8	3	10	1	34.82	
11	0600	5/2	23°50.0'	159°56.0'	74.9	12	14	74.5	70.0	1017	02	8	5	8	3	10	1	34.94	
12	0900	5/2	23°35.0'	160°11.5'	75.0	11	14	74.1	69.8	1018	00			8	3	XX	X	35.21	
13	1200	5/2	23°11.0'	160°27.5'	75.0	13	14	75.0	69.6	1017	00	8	2	7	3	XX	X	34.84	
14	1500	5/2	22°49.5'	160°42.5'	75.4	10	13	74.5	69.5	1016	02	8	2	7	3	XX	X	34.74	
15	1800	5/2	22°26.5'	160°57.5'	76.0	10	04	75.3	69.9	1018	02	1	3	8	2	12	1	34.57	
16	1900	5/2	22°28.0'	161°05.0'	76.3	10	14	75.3	69.8	1018	01	8	2	8	2	12	1		
17	2350	5/2	22°28.0'	161°05.0'	77.0	10	05	77.5	72.0	1017	02	8	4	8	2	10	1	34.57	
18	0150	5/3	22°26.5'	160°57.5'	77.2	10	05	78.2	71.5	1016	02	4	2	8	2	15	1	34.58	
19	0600	5/3	21°58.0'	161°20.0'	77.5	07	10	76.8	70.4	1017	02	8	3	8	2	09	1	34.57	
20	0900	5/3	21°39.0'	161°34.0'	77.5	08	08	76.6	70.8	1018	00	X	X	8	2	09	1	34.45	
21	1200	5/3	21°17.5'	161°51.5'	76.9	08	08	76.6	71.0	1017	00	8	2	7	2	09	1	34.50	
22	1500	5/3	20°56.0'	162°09.0'	77.5	08	10	76.4	70.0	1017	00	8	2	7	2	09	1	34.50	
23	1800	5/3	20°34.0'	162°27.0'	77.3	07	11	76.3	69.9	1017	02	8	1	8	2	11	1	34.58	
24	2100	5/3	20°13.0'	162°44.0'	77.9	07	10	78.2	71.4	1018	02	8	1	8	2	09	1	34.66	
25	0000	5/4	19°51.0'	163°01.5'	78.6	07	11	79.0	71.4	1017	02	8	1	8	3	12	1	34.53	
26	0300	5/4	19°42.5'	162°36.0'	77.9	05	12	77.7	71.7	1016	02	8	1	8	3	05	1	34.51	
27	0600	5/4	19°34.0'	162°10.0'	78.0	07	10	77.0	71.2	1017	03	8	6	8	3	07	1	34.52	
28	0900	5/4	19°26.0'	161°49.5'	78.1	07	12	76.3	71.9	1018	01	8	3	8	3	07	1	34.54	
29	1200	5/4	19°18.0'	161°24.0'	77.2	11	09	76.9	70.2	1016	03	8	7	7	3	XX	1	34.45	
30	1500	5/4	19°09.5'	160°59.0'	77.3	04	14	76.5	72.8	1015	02	8	7	7	3	XX	1	34.41	
31	1640	5/4	19°07.0'	160°58.5'	77.5	09	18	75.8	68.6	1016	16	8	6	7	3	09	1	34.41	
32	2210	5/4	19°05.0'	160°57.5'	77.7	09	16	78.2	71.5	1017	02	4	5	7	4	10	3	34.40	
33	0005	5/5	19°05.5'	160°53.5'	77.8	08	16	78.8	71.1	1015	01	8	1	8	4	08	3	34.52	
34	0300	5/5	19°20.0'	160°34.0'	77.5	07	13	78.1	71.3	1014	02	8	1	8	4	06	1	34.49	
35	0600	5/5	19°34.0'	160°12.0'	77.8	08	12	77.8	71.3	1016	03	8	4	8	3	08	1	34.45	
36	0900	5/5	19°47.0'	159°53.0'	77.0	08	10	77.8	71.8	1018	00	X	X	8	3	08	1	34.47	
37	1200	5/5	20°00.0'	159°31.0'	77.1	10	14	77.0	71.0	1016	00	X	8	7	4	XX	3	34.47	
38	1500	5/5	20°12.5'	159°10.0'	76.8	07	20	74.1	70.4	1016	00	X	8	7	4	XX	3	34.48	
39	1800	5/5	20°26'	158°47.0'	76.9	08	14	76.2	69.9	1017	01	8	6	8	4	08	3	34.57	
40	2100	5/5	20°42.0'	158°26.0'	76.0	08	16	76.8	69.8	1018	01	8	1	8	4	08	3	34.73	

[1] X indicates that no observation was recorded.

Table 4.--Summary of observations at bathythermograph lowerings, Charles H. Gilbert cruise 44 (con.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Baro-meter (mb.)	Wea-ther	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO4-P, µg at./L.
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T.)	Amt.		
41	0000	5/6	20°57.5'	158°08.5'	77.0	07	18	78.5	71.4	1017	03	8	4	7	4	06	3	34.57	
42	0025	5/7	21°24.0'	157°33.0'	75.9	06	19	78.0	71.5	1018	00	8	4	7	4	06	3	34.75	
43	0300	5/7	21°40.0'	157°23.0'	74.6	07	18	76.8	70.8	1017	03	8	5	7	4	06	3	34.95	
44	0600	5/7	21°57.5'	157°11.0'	74.3	08	25	75.6	71.0	1019	01	8	2	7	4	06	3	35.00	
45	0900	5/7	22°16.0'	156°55.0'	74.5	08	26	75.4	71.0	1020	02	8	2	7	4	06	3	34.95	
46	1205	5/7	22°31.0'	156°38.0'	74.4	08	22	75.6	70.0	1020	02	8	2	7	4	06	3	34.92	
47	1505	5/7	22°46.0'	156°22.5'	74.7	08	24	75.3	70.1	1019	80	6	6	7	4	06	3	34.95	
48	1800	5/7	23°01.5'	156°05.5'	73.5	07	23	73.2	69.3	1021	50	0	7	7	4	06	3	35.10	
49	2100	5/7	23°19.0'	155°50.0'	72.9	06	19	74.4	68.0	1022	01	8	5	8	4	06	4	35.18	
50	0000	5/8	23°27.0'	155°30.0'	74.7	06	22	77.1	69.3	1021	02	8	3	7	5	07	4	34.91	
51	0300	5/8	23°28.0'	155°07.0'	75.0	06	22	75.4	68.3	1021	02	8	3	7	5	07	4	34.88	
52	0600	5/8	23°27.0'	154°45.0'	75.0	05	22	73.2	69.0	1022	02	8	3	7	4	07	4	34.79	
53	0900	5/8	23°25.0'	154°25.0'	75.0	05	24	73.2	68.4	1023	00	X	X	7	5	07	4	34.76	
54	1200	5/8	23°26.0'	154°04.0'	74.8	06	21	75.4	69.2	1022	02	8	2	7	5	07	4	34.76	
55	1500	5/8	23°40.0'	153°47.5'	75.0	07	24	74.5	68.8	1022	15	6	6	7	5	07	4	34.78	
56	1800	5/8	23°55.0'	153°29.5'	74.6	07	22	74.4	68.7	1023	15	8	4	7	4	06	4	34.77	
57	2100	5/8	24°10.5'	153°14.0'	73.5	06	22	72.0	67.0	1024	15	6	6	7	5	07	4	35.10	
58	0000	5/9	24°30.0'	152°55.5'	74.1	06	18	73.7	65.4	1023	02	8	4	7	6	07	4	35.04	
59	0300	5/9	24°30.0'	152°30.0'	74.2	05	22	73.0	67.5	1021	02	8	4	7	5	07	4	34.85	
60	0600	5/9	24°30.5'	152°04.0'	72.9	05	24	69.9	65.2	1022	00	X	X	7	5	07	4	35.07	
61	0900	5/9	24°12.5'	151°52.0'	72.9	04	21	70.2	62.2	1023	00	X	X	7	5	XX	X	35.09	
62	1200	5/9	23°49.5'	151°42.0'	73.0	04	22	69.7	59.3	1021	00	8	5	7	5	XX	X	35.04	
63	1500	5/9	23°28.0'	151°53.5'	73.9	06	18	69.8	59.0	1020	02	8	2	7	5	08	4	34.83	
64	1800	5/9	23°02.5'	151°42.0'	74.0	04	14	71.4	63.5	1021	02	8	2	7	4	07	3	34.84	
65	2100	5/9	22°40.0'	151°27.0'	73.0	05	18	71.9	64.0	1021	03	6	6	7	4	06	1	35.12	
66	0000	5/10	22°21.5'	151°10.5'	73.6	07	15	71.4	65.7	1019	15	6	7	7	5	06	1	35.00	
67	0300	5/10	22°02.0'	150°53.0'	73.5	08	13	74.1	66.8	1018	15	6	6	7	4	06	1	35.01	
68	0600	5/10	21°42.0'	150°35.0'	74.1	10	10	72.0	65.6	1018	00	X	X	7	4	06	1	34.90	
69	0900	5/10	21°24.0'	150°19.0'	74.5	06	14	72.5	66.5	1019	00	X	X	7	4	06	1	34.83	
70	1200	5/10	21°03.5'	150°01.0'	74.6	04	15	72.7	67.8	1017	00	8	1	7	4	06	1	34.80	
71	1500	5/10	20°43.0'	149°42.5'	74.2	05	12	73.2	65.5	1016	03	3	5	7	4	05	1	34.81	
72	1800	5/10	20°24.0'	149°49.0'	74.5	05	15	73.4	67.6	1017	15	6	7	7	3	05	1	34.81	
73	2100	5/10	20°05.0'	150°07.5'	75.2	05	14	74.2	67.6	1017	15	6	7	7	3	05	1	34.73	
74	0000	5/11	19°40.0'	150°20.0'	75.8	07	16	74.8	67.9	1016	15	6	6	7	3	07	1	34.73	
75	0300	5/11	19°13.0'	150°33.0'	76.0	05	17	74.3	68.0	1014	15	6	6	7	3	06	1	34.66	
76	0600	5/11	18°45.0'	150°45.5'	75.8	05	15	73.7	66.6	1015	01	8	1	7	3	06	1	34.72	
77	0900	5/11	18°23.0'	150°56.5'	75.7	07	15	74.0	68.3	1016	00	X	X	7	3	06	1	34.71	
78	1200	5/11	17°55.5'	151°09.5'	75.7	05	16	74.7	68.9	1014	00	X	6	7	3	XX	1	34.64	
79	1500	5/11	17°28.5'	151°22.0'	75.5	03	20	73.4	67.5	1012	15	4	6	7	3	05	1	34.69	
80	1640	5/11	17°19.0'	151°30.0'	75.7	05	14	73.7	65.9	1013	15	8	6	7	3	04	1	34.66	

Table 4.--Summary of observations at bathythermograph lowerings, Charles H. Gilbert cruise 44 (con.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Barometer (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO4-P, (ug. at./l.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F)	Wet bulb (°F.)			Type	Cover			Dir. (°T.)	Amt.		
81	2200	5/11	17°13.0'	151°30.0'	76.0	02	16	75.8	68.9	1013	02	4	6	8	4	36	1	34.71	
82	2355	5/11	17°17.5'	151°25.5'	76.0	04	16	76.5	69.5	1012	02	1	6	8	3	05	1	34.39	
83	0300	5/12	16°53.5'	151°36.0'	76.7	04	16	78.1	69.5	1012	15	8	6	8	3	07	1	34.43	
84	0600	5/12	16°31.0'	151°49.5'	76.8	03	19	75.2	67.8	1013	01	X	5	7	3	04	1	34.67	
85	0900	5/12	16°12.5'	152°02.0'	77.1	05	19	75.0	68.0	1014	00	X	X	7	3	04	1	34.45	
86	1200	5/12	15°50.0'	152°18.5'	77.4	05	19	75.7	68.7	1012	00	8	6	7	3	04	1	34.44	
87	1500	5/12	16°12.0'	152°29.0'	76.7	07	18	77.3	69.2	1012	02	8	7	7	3	04	1	34.52	
88	1800	5/12	16°34.0'	152°39.0'	76.5	04	17	74.8	67.2	1013	01	4	6	7	3	03	1	34.54	
89	2100	5/12	16°57.0'	152°50.0'	76.3	07	18	74.8	67.0	1014	01	8	2	7	3	03	1	34.61	
90	0000	5/13	17°21.5'	153°00.0'	76.5	05	15	75.6	68.8	1013	01	8	1	8	3	04	1	34.61	
91	0300	5/13	17°46.0'	153°10.0'	76.6	07	19	77.7	70.1	1013	02	8	2	8	5	05	3	34.61	
92	0600	5/13	18°11.0'	153°19.0'	75.4	06	16	74.6	68.8	1015	03	8	5	8	4	05	3	34.72	
93	0900	5/13	18°27.0'	153°23.0'	75.9	07	09	73.4	68.5	1016	52	X	X	6	4	XX	X	34.70	
94	1200	5/13	18°51.0'	153°30.5'	76.0	10	12	74.6	68.5	1016	00	8	2	6	3	04	1	34.56	
95	1500	5/13	19°14.0'	153°38.0'	75.8	07	14	76.6	68.7	1016	15	6	4	7	3	03	1	34.59	
96	1800	5/13	19°37.0'	153°45.5'	75.4	08	13	75.2	67.0	1018	15	8	5	7	3	05	1	34.58	
97	2100	5/13	20°01.0'	153°53.5'	75.8	07	15	73.5	68.6	1018	01	4	5	7	3	04	1	34.66	
98	0000	5/14	20°24.5'	154°03.0'	75.8	06	16	74.7	70.2	1017	03	4	6	7	3	04	1	34.70	
99	0300	5/14	20°45.0'	154°12.0'	75.7	07	15	75.4	69.6	1017	02	4	6	7	3	05	1	34.68	
100	0600	5/14	21°06.0'	154°21.5'	74.8	07	15	74.0	67.8	1019	02	4	6	7	3	05	1	34.75	
101	1000	5/14	21°29.5'	154°21.0'	74.5	06	22	73.6	67.8	1019	01	X	4	7	3	05	1	34.77	
102	1400	5/14	21°57.0'	154°22.5'	74.3	08	21	73.4	68.5	1019	02	X	2	7	3	06	1	34.82	
103	1837	5/14	22°23.0'	154°29.0'	74.9	07	23	73.9	68.4	1021	15	6	7	6	3	07	1	34.75	
104	2350	5/14	22°29.0'	154°25.0'	75.2	08	15	75.0	69.2	1020	02	8	2	7	4	06	3	34.74	
105	0145	5/15	22°31.5'	154°17.5'	75.0	09	16	75.9	70.4	1019	25	8	3	7	4	06	3	34.75	
106	0600	5/15	23°01.0'	154°22.0'	75.0	09	16	74.4	68.8	1020	15	8	5	7	3	06	1	34.75	
107	1000	5/15	23°23.0'	154°22.0'	75.0	09	18	73.8	69.4	1021	00	X	X	7	3	06	1	34.77	
108	1400	5/15	23°48.0'	154°20.5'	75.0	07	15	73.0	69.3	1020	00	8	4	6	3	06	1	34.75	
109	1650	5/15	24°01.0'	154°26.5'	74.8	07	20	72.6	68.6	1021	25	6	6	7	4	07	3	34.75	
110	2155	5/15	24°02.5'	154°19.5'	75.0	08	18	74.0	68.5	1021	02	8	4	7	4	08	3	34.76	
111	2335	5/15	24°03.0'	154°13.5'	75.0	09	16	74.2	68.6	1020	02	8	4	7	4	10	3	34.77	
112	0300	5/16	23°35.5'	154°26.0'	75.0	09	22	74.5	69.0	1019	02	8	2	7	4	10	3	34.76	
113	0600	5/16	23°11.0'	154°38.0'	74.9	09	20	74.3	68.8	1020	02	8	2	7	4	09	3	34.77	
114	0900	5/16	22°53.5'	154°46.5'	75.2	09	20	74.0	69.3	1020	03	8	4	7	3	09	3	34.74	
115	1205	5/16	22°32.5'	154°58.0'	75.5	08	20	74.5	70.0	1019	02	8	4	7	3	09	3	34.66	
116	1500	5/16	22°12.0'	155°10.0'	74.5	08	19	74.3	69.3	1018	02	8	3	7	3	10	3	34.84	
117	1800	5/16	21°47.0'	155°24.0'	73.5	11	21	72.8	68.7	1019	81	6	8	6	3	09	3	35.18	
118	2100	5/16	21°18.5'	155°33.5'	74.5	09	16	75.1	70.0	1019	01	8	2	7	3	09	3	35.03	
119	0000	5/17	20°52.0'	155°46.0'	74.8	09	17	75.3	70.6	1018	15	6	2	7	3	10	3	34.97	
120	0300	5/17	20°25.0'	155°58.5'	76.3	08	21	76.7	71.5	1016	02	4	2	7	4	07	3	34.52	

Table 4.--Summary of observations at bathythermograph lowerings, Charles H. Gilbert cruise 44 (con.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Baro-meter (mb.)	Wea-ther	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO4-P, (ug. at./l.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T.)	Amt.		
121	0600	5/17	20°03.0'	156°14.5'	77.0	04	21	76.3	68.8	1016	03	4	6	7	3	04	1	34.50	
122	0900	5/17	19°44.0'	156°25.7'	76.9	09	15	77.8	69.5	1017	02	4	6	7	3	XX	1	34.52	
123	1200	5/17	19°21.0'	156°42.0'	76.6	32	03	77.5	70.9	1016	02	4	5	7	3	XX	1	34.70	
124	1500	5/17	18°57.0'	157°00.0'	76.8	29	04	77.2	70.5	1015	02	4	6	7	3	XX	1	34.82	
125	1800	5/17	18°33.5'	157°14.5'	76.5	10	18	77.8	71.2	1017	02	4	6	7	3	10	4	34.58	
126	2100	5/17	18°09.0'	157°32.5'	77.2	10	20	76.8	72.2	1017	02	3	6	7	4	09	4	34.46	
127	0000	5/18	17°41.0'	157°51.5'	77.3	10	22	77.7	73.0	1015	15	3	7	7	4	09	4	34.47	
128	0300	5/18	17°57.5'	157°57.0'	77.3	09	18	77.5	73.5	1015	02	4	5	7	5	08	4	34.50	
129	0600	5/18	18°23.0'	157°59.5'	76.9	10	18	76.6	72.3	1016	01	4	3	7	3	07	3	34.49	
130	0900	5/18	18°42.0'	157°57.0'	77.2	10	19	77.0	72.5	1018	00	X	X	7	4	XX	X	34.46	
131	1200	5/18	19°07.0'	157°56.0'	76.8	10	13	76.8	71.9	1017	00	4	6	7	3	07	1	34.50	
132	1500	5/18	19°34.0'	157°56.5'	76.8	09	03	74.8	72.5	1016	15	6	4	7	3	07	1	34.54	
133	1800	5/18	20°02.5'	157°57.5'	76.8	10	14	76.0	72.4	1018	15	6	5	7	2	08	1	34.55	
134	2100	5/18	20°32.0'	157°55.5'	77.2	04	10	76.0	72.0	1018	02	6	5	7	3	07	1	34.48	
135	0000	5/19	20°54.0'	157°57.0'	77.8	05	07	77.8	72.4	1017	02	8	3	7	3	05	1	34.58	
136	2100	5/20	21°04.0'	158°05.0'	77.0	00	00	77.2	72.0	1016	00	8	6	7	0	15	1	34.66	
137	0010	5/21	21°00.0'	158°14.0'	77.9	20	07	77.0	72.0	1015	02	4	7	7	1	18	1	34.73	
138	0300	5/21	20°41.5'	158°28.0'	77.6	20	06	77.1	72.0	1014	02	8	4	7	1	15	1	34.73	
139	0600	5/21	20°24.0'	158°43.5'	77.3	17	06	76.4	71.8	1015	03	8	6	7	1	17	1	34.58	0.25
140	0900	5/21	20°05.0'	158°52.5'	77.2	20	05	76.0	71.7	1016	01	4	4	7	1	17	1	34.53	
141	1200	5/21	19°45.0'	159°06.5'	77.8	19	06	76.1	71.0	1015	02	4	2	7	1	16	1	34.32	
142	1500	5/21	19°23.5'	159°21.5'	77.7	18	05	76.0	71.0	1014	15	4	2	7	1	16	1	34.32	
143	1800	5/21	19°08.5'	159°40.0'	78.2	13	07	76.8	71.0	1015	02	8	2	7	1	13	1	34.32	
144	2100	5/21	18°53.0'	159°59.0'	79.2	08	03	77.0	71.0	1016	02	8	2	8	1	13	1	34.30	
145	0000	5/22	18°37.0'	160°20.0'	80.6	07	04	79.1	71.2	1015	02	8	2	8	1	14	1	34.41	
146	0300	5/22	18°20.0'	160°41.5'	79.5	12	07	77.7	71.7	1014	02	8	1	8	1	14	1	34.39	
147	0600	5/22	18°03.0'	161°03.0'	78.9	13	06	77.5	71.8	1014	02	8	1	8	1	14	2	34.34	0.18
148	0900	5/22	18°22.5'	161°01'	78.4	07	06	77.2	71.8	1016	02	8	1	8	1	14	2	34.57	
149	1200	5/22	18°45.0'	161°03.0'	78.0	00	11	74.9	71.8	1015	02	8	2	8	1	33	2	34.57	
150	1500	5/22	19°07.5'	161°04.0'	77.5	03	17	75.0	72.0	1014	15	6	6	7	3	33	3	34.52	
151	1800	5/22	19°29.5'	161°05.0'	77.2	02	19	74.0	70.0	1015	15	6	8	6	3	35	3	34.52	
152	2100	5/22	19°51.5'	161°06.5'	78.0	02	19	75.0	68.0	1016	02	6	8	6	3	36	3	34.37	
153	0000	5/23	20°17.5'	161°07.0'	77.8	04	17	75.8	67.8	1015	02	4	6	6	3	02	3	34.41	
154	0300	5/23	20°41.0'	161°06.0'	77.9	04	18	75.0	66.7	1014	02	6	7	6	3	02	3	34.34	
155	0600	5/23	21°05.0'	161°06.0'	77.4	05	17	74.2	65.8	1015	01	6	6	7	3	36	3	34.35	0.21
156	0900	5/23	21°27.0'	161°03.0'	77.0	05	13	72.5	63.6	1017	00	X	X	7	3	36	3	34.55	
157	1200	5/23	21°49.5'	161°03.0'	75.4	03	10	73.0	64.5	1016	00	4	6	7	3	02	3	34.92	
158	1500	5/23	22°12.5'	161°03.5'	75.4	00	06	72.0	61.9	1015	00	4	6	7	2	02	1	34.89	
159	2105	5/23	22°28.0'	160°37.0'	75.9	02	08	78.0	63.2	1017	15	6	7	7	2	36	1	34.84	
160	0000	5/24	22°49.0'	160°37.0'	75.4	03	12	73.5	64.7	1016	02	6	6	7	2	36	1	34.88	

Table 4.--Summary of observations at bathythermograph lowerings, *Charles H. Gilbert* cruise 44 (con.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Barometer (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO_4-P, (ug. at./l.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T)	Amt.		
161	0300	5/24	22°49.0'	161°03.0'	75.9	03	12	74.0	67.0	1015	02	8	5	7	3	36	4	34.89	
162	0600	5/24	23°07.0'	161°10.0'	76.2	04	11	72.0	64.6	1016	15	6	7	7	3	02	4	34.76	0.19
163	0900	5/24	23°27.0'	161°05.2'	75.6	03	10	70.2	65.0	1017	01	4	4	7	3	02	4	34.88	
164	1200	5/24	23°54.5'	161°06.0'	74.8	32	08	69.0	64.5	1016	25	8	2	7	3	02	4	34.99	
165	1500	5/24	24°22.0'	161°07.0'	74.8	32	03	67.0	63.4	1016	15	6	7	6	2	02	4	34.82	
166	1800	5/24	24°49.0'	161°08.0'	74.1	03	07	68.0	63.5	1017	15	6	7	6	2	01	1	34.96	
167	2100	5/24	24°37.5'	160°48.0'	74.0	06	05	70.6	64.3	1017	01	8	2	7	2	01	1	35.11	
168	0000	5/25	24°23.0'	160°28.0'	76.1	06	06	72.0	64.7	1017	02	8	2	7	2	01	4	34.83	
169	0300	5/25	24°07.0'	160°04.5'	75.9	05	08	72.5	65.5	1016	15	8	5	7	2	02	4	34.72	
170	0600	5/25	23°49.0'	159°42.0'	76.0	07	09	72.3	63.8	1017	03	6	7	7	2	02	1	34.68	0.15
171	0900	5/25	23°31.0'	159°25.0'	74.4	11	08	72.2	64.0	1018	01	6	2	7	2	02	1	35.09	
172	1200	5/25	23°10.0'	159°03.0'	75.2	10	10	75.2	66.5	1016	00	4	7	6	2	XX	1	34.86	
173	1500	5/25	22°49.0'	158°40.0'	74.8	09	13	73.4	66.7	1016	00	4	6	6	2	09	1	35.06	
174	1800	5/25	22°29.0'	158°19.5'	74.4	07	12	73.0	67.4	1017	25	6	7	7	3	09	1	35.05	
175	2105	5/25	22°09.0'	158°02.5'	75.2	08	11	75.0	70.2	1017	01	8	5	7	2	09	1	35.07	
176	0000	5/26	21°52.5'	157°55.5'	76.0	09	10	76.0	71.6	1016	02	8	2	7	2	10	1	34.87	
177	0300	5/27	21°48.0'	157°21.0'	76.8	12	15	76.2	72.3	1014	02	4	6	8	3	11	1	34.67	
178	0600	5/27	22°02.5'	156°56.5'	75.1	12	13	75.2	71.6	1016	01	6	5	8	3	11	1	35.13	0.08
179	0900	5/27	22°15.0'	156°36.0'	75.3	13	12	75.0	71.2	1018	00	X	X	7	3	11	1	34.92	
180	1200	5/27	22°33.0'	156°12.5'	75.1	14	17	74.9	70.8	1016	00	4	2	7	3	12	1	35.07	
181	1500	5/27	22°51.0'	155°49.0'	75.1	15	14	74.9	70.0	1017	00	1	4	7	3	12	1	35.05	
182	1800	5/27	23°12.0'	155°27.0'	76.2	14	09	75.8	70.0	1018	03	1	7	7	2	12	1	34.75	
183	2100	5/27	23°33.0'	155°03.0'	76.2	13	11	75.9	70.7	1019	02	8	7	7	2	12	1	34.78	
184	0000	5/28	23°49.0'	154°38.0'	76.6	13	12	75.9	70.0	1017	02	8	6	7	2	11	1	34.82	
185	0300	5/28	24°06.0'	154°13.0'	76.4	11	12	75.6	69.1	1017	02	5	7	7	2	11	1	34.78	
186	0600	5/28	24°26.0'	153°44.0'	75.0	12	11	74.8	68.5	1019	03	6	6	7	2	11	1	35.05	0.13
187	0900	5/28	24°38.0'	153°21.0'	75.0	12	11	74.2	69.0	1020	00	X	X	7	2	11	1	34.92	
188	1200	5/28	24°51.0'	152°57.0'	74.9	12	10	73.5	68.9	1018	00	8	2	7	2	11	1	35.08	
189	1500	5/28	24°26.5'	152°56.5'	75.2	13	12	73.7	69.0	1018	00	2	2	7	2	12	1	34.81	
190	1800	5/28	24°00.0'	152°56.0'	76.0	11	10	74.5	69.2	1019	03	2	7	7	2	13	1	34.81	
191	2100	5/28	23°32.5'	152°52.5'	75.9	11	10	75.4	69.7	1019	02	2	7	7	2	12	1	34.72	
192	0000	5/29	23°02.5'	152°48.0'	76.0	12	12	75.6	70.0	1018	15	2	7	7	3	13	1	34.75	
193	0300	5/29	22°32.0'	152°44.0'	75.8	12	10	75.4	70.0	1018	02	2	7	7	3	13	1	34.82	
194	0600	5/29	22°01.0'	152°40.0'	75.2	14	09	75.0	69.0	1019	01	X	2	7	3	11	1	34.99	0.14
195	0900	5/29	21°47.0'	152°39.0'	75.1	14	09	75.0	70.4	1019	00	X	X	7	3	11	1	34.99	
196	1200	5/29	21°18.0'	152°44.0'	75.7	08	17	75.1	70.7	1018	00	X	7	6	3	09	1	34.83	
197	1500	5/29	20°48.5'	152°49.0'	76.6	10	21	74.1	71.1	1016	25	6	7	6	4	09	1	34.75	
198	1800	5/29	20°19.0'	152°53.0'	77.0	08	20	75.2	72.1	1018	15	6	6	7	4	10	1	34.69	
199	2100	5/29	19°49.5'	152°58.0'	77.0	09	15	76.8	72.5	1018	25	6	6	7	3	09	3	34.75	
200	0000	5/30	19°20.5'	153°00.5'	77.4	07	19	77.2	73.1	1016	15	8	3	7	3	11	3	34.75	

Table 4.--Summary of observations at bathythermograph lowerings, *Charles H. Gilbert* cruise 44 (con.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Barometer (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO_4-P, (ug. at./l.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T.)	Amt.		
201	0300	5/30	18°50.5'	153°02.5'	77.2	09	17	77.2	73.1	1015	15	8	4	7	3	10	3	34.65	
202	0600	5/30	18°22.0'	153°04.0'	77.0	09	18	76.6	72.8	1017	00	X	X	7	4	09	3	34.58	0.19
203	0900	5/30	17°52.5'	153°05.0'	77.4	09	19	75.8	73.0	1017	00	X	X	6	4	09	3	34.66	
204	1200	5/30	17°24.0'	153°06.0'	77.2	07	19	76.2	71.5	1016	00	8	2	6	3	10	3	34.60	
205	1500	5/30	16°55.5'	153°07.0'	77.8	08	21	76.0	70.7	1015	00	4	4	6	3	10	3	34.54	
206	1800	5/30	17°10.0'	153°30.0'	77.5	07	16	76.6	70.2	1017	01	8	2	7	3	09	3	34.57	
207	2100	5/30	17°24.5'	153°55.0'	77.8	07	16	76.8	71.1	1017	03	8	4	7	3	07	3	34.57	
208	0000	5/31	17°40.0	154°21.0'	77.6	05	15	77.1	70.3	1015	02	8	2	7	4	08	3	34.73	
209	0300	5/31	17°56.5'	154°47.0'	77.5	07	15	77.0	70.8	1014	02	8	2	7	3	06	3	34.67	
210	0600	5/31	18°13.0'	155°13.5'	77.3	06	17	76.3	70.5	1016	02	8	2	6	3	05	3	34.59	0.16
211	0900	5/31	18°25.0'	155°33.0'	77.3	06	22	76.0	70.2	1017	00	X	X	6	3	05	3	34.55	
212	1600	5/31	19°08.0'	156°16.0'	77.1	06	05	76.5	71.0	1015	15	1	2	6	3	XX	X	34.59	
213	0300	6/1	20°12.0'	156°16.0'	77.4	06	22	77.0	71.1	1014	02	2	1	7	3	05	1	34.68	
214	0600	6/1	20°20.5'	156°36.0'	76.5	07	18	75.4	70.0	1016	03	1	2	7	3	06	3	34.73	
215	0900	6/1	20°37.0'	157°02.0'	78.2	13	07	76.0	67.8	1017	00	X	X	7	2	XX	X	34.48	
216	1200	6/1	20°53.0'	157°27.5'	77.1	08	19	75.2	70.0	1016	00	X	1	7	2	XX	X	34.66	
217	1500	6/1	21°13.5'	157°51.0'	76.0	06	15	75.0	70.0	1016	00	8	1	7	2	XX	X	34.81	

Table 5.--Summary of observations at bathythermograph lowerings, Charles H. Gilbert cruise 45
(Recording and coding of data follows U.S. Navy Hydrographic Office, 1956.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Baro-meter (mb.)	Wea-ther	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO4-P, (ug. at./l.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T.)	Amt.		
1	2200	7/17	21°09'	158°01'	78.6	06	18	79.0	75.0	1019	00	8	2	8	3	08	1	34.54	
2	0100	7/18	20°51'	158°21'	79.5	07	15	80.0	75.5	1018	03	8	6	8	3	08	1	34.60	
3	0400	7/18	20°31'	158°43'	79.5	06	08	79.5	75.2	1017	02	8	4	8	2	07	1	34.59	
4	0700	7/18	20°16'	158°54'	79.0	06	07	79.0	76.0	1019	02	X 1/	X	X	2	07	1	34.50	
5	1000	7/18	19°56'	159°11'	78.9	07	13	79.1	75.3	1019	02	X	X	X	2	07	1	34.49	
6	1300	7/18	19°36'	159°28'	78.5	07	13	78.3	74.6	1017	02	8,1	4	5	2	07	1	34.40	
7	1600	7/18	19°15'	159°46'	78.4	07	12	78.4	75.0	1018	02	8,1	5	7	2	07	1	34.49	
8	1900	7/18	18°54'	160°04'	78.7	10	14	79.7	74.8	1016	03	1,8	6	7	3	10	1	34.40	
9	2200	7/18	18°34'	160°21'	79.0	11	12	79.8	75.4	1018	02	8	6	7	2	10	1	34.53	
10	0100	7/19	18°15'	160°40'	79.7	11	12	80.2	74.5	1016	01	8	2	7	2	10	1	34.50	
11	0400	7/19	18°00'	161°01'	79.5	10	10	79.6	75.0	1016	02	8	3	8	3	10	1	34.54	
12	0700	7/19	18°13'	161°17'	79.6	07	16	79.8	75.3	1015	00	X	X	X	2	08	1	34.43	
13	1000	7/19	18°31'	161°36'	79.5	08	17	79.0	75.2	1017	02	8	4	5	3	07	1	34.48	
14	1300	7/19	18°46'	161°56'	79.2	08	17	78.8	74.0	1017	02	8	4	5	3	07	1	34.49	
15	1600	7/19	19°03'	162°15'	79.5	08	14	79.1	74.0	1016	02	1,8	2	7	3	07	1	34.44	
16	1900	7/19	19°19'	162°32'	79.5	10	17	80.3	74.4	1015	01	8	1	7	3	05	4	34.47	
17	2200	7/19	19°39'	162°51'	79.9	09	17	80.9	74.7	1018	02	8	3	8	3	09	1	34.46	
18	0100	7/20	20°00'	163°09'	80.0	09	15	80.1	74.8	1017	02	8	3	8	3	09	1	34.47	
19	0400	7/20	20°22'	163°27'	80.0	09	14	79.2	75.1	1017	02	8	2	8	3	09	1	34.43	
20	0700	7/20	20°40'	163°40'	80.0	09	19	80.0	75.0	1016	25	8	2	7	3	09	1	34.26	
21	1000	7/20	21°01'	164°00'	78.8	09	12	79.1	73.8	1019	02	8	4	5	3	09	1	34.83	
22	1300	7/20	21°21'	164°18'	78.8	10	16	78.8	74.4	1019	02	8	4	5	3	09	1	34.77	
23	1600	7/20	21°41'	164°36'	78.5	09	14	77.8	73.5	1019	02	1,8	2	7	3	09	1	34.72	
24	1900	7/20	22°00'	164°53'	79.0	08	16	79.4	74.6	1017	03	8,6	3	7	3	09	1	34.82	
25	2200	7/20	22°18'	165°11'	79.4	08	10	78.2	73.8	1018	14	8,6	5	7	2	09	1	34.76	
26	0100	7/21	22°39'	165°32'	79.7	09	13	79.5	74.6	1017	02	8,6	5	7	2	09	1	34.66	
27	0400	7/21	23°00'	165°52'	79.9	09	12	79.6	74.0	1019	02	8	3	8	2	09	1	34.79	
28	0700	7/21	23°20'	166°09'	79.5	09	15	79.5	73.5	1017	01	8	2	7	2	09	1	34.70	
29	2200	7/22	24°03'	166°05'	79.4	06	10	78.3	72.6	1018	00	6,3	5	7	2	08	1	34.94	
30	0100	7/23	24°11'	165°38'	79.3	09	11	78.3	73.5	1017	01	5,8	5	7	2	10	1	35.11	
31	0400	7/23	24°19'	165°10'	79.3	07	11	79.1	72.5	1016	50	8,6	6	7	2	10	1	35.01	
32	0700	7/23	24°25'	164°46'	78.7	09	10	77.5	72.5	1019	02	8,6	7	7	2	09	1	34.99	
33	1000	7/23	24°37'	164°18'	78.7	07	09	75.7	70.8	1017	00	X	X	5	2	09	1	34.97	
34	1300	7/23	24°47'	163°51'	78.3	07	08	77.6	72.0	1016	00	8	2	5	2	09	1	34.95	
35	1600	7/23	24°59'	163°23'	78.6	08	08	77.0	70.5	1017	00	8	4	7	2	09	1	34.73	
36	1900	7/23	25°07'	162°54'	78.0	08	09	80.0	72.0	1018	02	8	4	7	1	09	1		
37	2200	7/23	25°16'	162°24'	79.8	07	02	79.4	71.8	1017	01	8	1	7	1	09	1	34.93	
38	0100	7/24	25°23'	161°56'	83.7	00	00	80.6	71.5	1017	03	8	2	7	0	08	1	34.77	
39	0400	7/24	25°31'	161°29'	81.4	07	02	77.9	71.6	1016	15	8	3	7	1	08	3	34.85	
40	0930	7/24	25°55'	161°01'	78.1	09	08	78.2	73.7	1018	00	8	3	7	1	08	1	35.14	

1/ X indicates that no observation was recorded.

Table 5.--Summary of observations at bathythermograph lowerings, Charles H. Gilbert cruise 45 (con.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Baro-meter (mb.)	Wea-ther	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO4-P, (ug. at./1.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T.)	Amt.		
41	1200	7/24	25°40'	160°45'	78.6	09	07	76.6	73.0	1017	01	8	2	7	1	09	3	35.16	
42	1300	7/24	25°31'	160°40'	78.6	10	06	77.2	73.0	1017	02	8	2	7	1	09	3	35.18	
43	1600	7/24	25°06'	160°22'	78.7	00	00	74.8	70.0	1017	15	8,6	7	6	1	10	1	34.89	
44	1900	7/24	24°41'	160°05'	79.1	11	05	79.8	73.8	1018	01	8,6	2	7	1	11	1	34.87	
45	2200	7/24	24°16'	159°47'	80.2	15	04	80.4	73.3	1018	02	8	2	7	1	11	1	35.03	
46	0100	7/25	23°51'	159°30'	81.1	11	06	80.3	72.7	1018	02	8	2	7	1	11	1	35.00	
47	0400	7/25	23°27'	159°13'	79.8	07	08	78.3	73.8	1017	02	8	2	7	1	09	1	34.91	
48	0700	7/25	23°06'	158°57'	80.0	09	06	79.2	74.8	1018	03	8	4	7	1	09	1	34.37	
49	1000	7/25	22°45'	158°41'	79.0	09	08	79.0	75.3	1018	15	8	4	7	1	09	1	34.87	
50	1300	7/25	22°24'	158°21'	78.5	09	08	77.2	74.0	1017	15	8	6	7	1	09	1	34.85	
51	1620	7/25	21°59'	157°59'	78.2	08	08	78.2	74.8	1017	15	1,6,8	6	7	1	07	1	34.76	
52	1900	7/25	22°14'	157°35'	78.4	07	02	81.0	76.1	1018	01	6,8	4	7	1	07	1	34.75	
53	2200	7/25	22°22'	157°22'	80.2	10	07	81.4	75.7	1017	03	1,2,5,8	5	7	1	04	1	34.81	
54	0130	7/26	22°31'	157°03'	80.3	13	10	82.4	77.6	1016	15	8,2,5	4	7	1	04	1	34.89	
55	0400	7/26	22°41'	156°38'	80.2	13	11	80.0	75.4		02	8,1	4	7	1	05	1	34.74	
56	0700	7/26	22°52'	156°13'	79.5	11	09	80.1	76.1	1017	02	8,1	4	7	1	06	1	34.74	
57	1000	7/26	23°06'	155°47'	78.7	07	11	79.3	76.0	1017	03	8	5	7	2	06	1	34.87	
58	1300	7/26	23°21'	155°22'	78.5	07	17	79.1	74.5	1017	15	8,3	5	7	3	06	1	34.83	
59	1600	7/26	23°37'	154°58'	77.0	11	16	77.3	72.8	1017	15	8,4	6	7	3	07	1	34.81	
60	1900	7/26	24°00'	154°41'	77.4	11	16	78.0	73.3	1019	03	8,5	6	7	3	08	1	34.98	
61	2200	7/26	24°23'	154°24'	77.6	06	09	82.0	75.0	1019	02	8,2	5	7	2	07	1	34.99	
62	0100	7/27	24°45'	154°05'	77.2	06	12	78.1	72.0	1018	02	8,2	4	7	3	07	1	35.03	
63	0400	7/27	25°08'	153°46'	77.1	10	11	78.3	71.7	1018	03	4,8	6	7	2	07	1	35.08	
64	0700	7/27	25°29'	153°27'	76.7	10	14	77.1	70.1	1020	00	X	X	5	2	08	1	34.36	
65	1055	7/27	25°58'	152°59'	77.1	10	16	77.5	70.2	1019	00	X	X	6	3	08	1	34.76	
66	1300	7/27	25°39'	152°57'	77.1	10	17	77.4	70.5	1019	01	8,6	5	7	3	09	1	35.08	
67	1600	7/27	25°09'	152°55'	77.2	10	14	75.6	69.7	1019	01	1,8	3	7	3	09	1	35.08	
68	1900	7/27	24°41'	152°54'	77.0	10	12	76.8	71.1	1020	15	8,1,4	6	7	2	10	1	35.09	
69	2200	7/27	24°13'	152°55'	77.7	10	15	78.1	72.3	1020	01	8,1,2	5	7	2	10	1	35.02	
70	0100	7/28	23°46'	152°54'	77.5	10	10	78.0	70.9	1018	01	8,1	2	7	2	10	1	34.99	
71	0400	7/28	23°18'	152°53'	78.0	08	14	78.5	71.3	1018	02	8	2	7	3	09	1	34.90	
72	0700	7/28	22°52'	152°49'	78.1	08	17	76.7	72.2	1019	00	X	X	5	3	09	1	34.87	
73	1000	7/28	22°23'	152°49'	79.0	09	18	78.0	73.1	1018	00	8	6	6	3	09	1	34.79	
74	1300	7/28	21°54'	152°50'	77.7	09	11	76.7	72.2	1017	02	8	6	6	3	09	1	34.74	
75	1600	7/28	21°25'	152°50'	77.5	09	12	75.7	73.6	1017	25	0,8	7	7	3	09	1	34.76	
76	1900	7/28	20°57'	152°50'	78.0	08	10	77.5	74.8	1017	15	8,6	6	7	2	09	1	34.80	
77	2200	7/28	20°28'	152°50'	78.7	08	11	81.0	74.8	1016	01	8,6	4	7	2	09	1	34.82	
78	0100	7/29	20°00'	152°52'	78.4	08	10	79.5	74.8	1015	50	8,6	6	7	2	08	1	34.77	
79	0400	7/29	19°32'	152°54'	78.1	06	14	78.3	74.6	1015	01	8	2	7	3	08	1	34.78	
80	0700	7/29	19°08'	152°55'	77.3	08	14	77.9	74.3	1016	02	8,6	2	5	3	08	1	34.79	

Table 5.--Summary of observations at bathythermograph lowerings, Charles H. Gilbert cruise 45 (con.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Barometer (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO4-P, (ug. at./l.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T.)	Amt.		
81	1000	7/29	18°39'	152°56'	77.8	08	14	78.5	74.9	1015	02	X	5	7	3	08	1	34.78	
82	1300	7/29	18°10'	152°59'	77.8	09	15	77.6	73.5	1015	02	8	5	7	3	09	1	34.78	
83	1600	7/29	17°38.5'	153°03.0'	77.8	07	14	78.5	74.6	1013	01	8	2	7	3	09	1	34.82	
84	2000	7/29	16°59.0'	153°04.0'	78.5	09	12	79.9	74.8	1014	01	8,6	4	7	3	09	1	34.78	
85	2200	7/29	16°57.0'	153°24.5'	78.6	09	12	85.0	78.0	1014	02	8,6	4	7	3	09	1	34.78	
86	0100	7/30	16°53.0'	153°54.0'	78.7	09	09	83.0	75.8	1013	02	8	4	7	2	09	1	34.75	
87	0400	7/30	16°50.0'	154°24.0'	78.7	09	13	82.4	75.3	1012	03	4,8	5	7	2	09	1	34.73	
88	0700	7/30	16°48.5'	154°48.0'	78.4	07	12	78.7	74.0	1014	02	8,6	2	5	2	09	1	34.67	
89	1000	7/30	16°50.0'	155°17.0'	78.5	07	11	78.8	73.9	1014	01	8	1	5	2	09	1	34.69	
90	1400	7/30	16°52.0'	155°55.0'	78.5	06	11	78.5	74.5	1013	02	8	2	7	2	08	1	34.67	
91	1600	7/30	17°09.5'	156°04.0'	78.5	06	09	77.3	74.5	1013	02	8	3	7	2	07	1	34.66	
92	1900	7/30	17°37.0'	156°19.0'	78.4	09	14	79.6	74.6	1014	01	8	2	7	2	08	1	34.68	
93	2200	7/30	18°06.0'	156°33.0'	79.1	09	12	79.1	74.8	1014	03	8,4	5	7	2	08	1	34.71	
94	0100	7/31	18°33.0'	156°47.0'	79.6	09	13	79.7	74.0	1013	02	8,4,1	5	7	2	09	1	35.09	
95	0400	7/31	19°00.5'	157°01.0'	79.6	09	05	78.5	74.0	1014	15	8,1	6	7	2	09	1	34.77	
96	0700	7/31	19°25.5'	157°10.0'	79.2	05	15	80.6	76.0	1014	01	8	2	7	1	08	1	34.65	
97	1000	7/31	19°52.0'	157°20.0'	78.6	06	16	79.9	75.3	1014	00	X	X	7	2	08	1	34.67	
98	1300	7/31	20°18.0'	157°29.0'	80.5	09	17	79.5	75.0	1014	00	X	2	7	2	08	1	34.60	
99	0330	8/3	21°15.0'	158°10.0'	80.3	07	17	79.9	74.0	1015	03	8,6	6	7	3	08	1		
100	2255	8/3	21°07.0'	158°31.0'	80.3	08	17	82.2	74.1	1014	03	8,6	6	7	3	08	1		
101	0255	8/4	21°20.0'	158°14.0'	80.4	06	16	81.8	72.3	1013	01	8.6	2	7	2	07	1		
102	2215	8/4	21°27.5'	158°19.5'	80.8	05	05	86.9	71.9	1014	01	8.6	2	8	2	05	1		
103	1930	8/9	21°13.5'	158°02.0'	79.0	05	09	81.0	75.7	1017	15	6.8	6	7	1	05	1		
104	0325	8/10	21°18.5'	158°14.0'	80.4	06	15	81.8	75.4	1015	01	6.8	4	7	1	08	1		
105	0335	8/15	21°09.5'	157°55.0'	78.9	06	20	79.1	72.6	1015	00	6.8	3	7	3	07	2		
106	2335	8/17	21°07.0'	157°47.5'	80.2	27	07	82.9	74.2	1012	00	6.8	4	8	1	22	1		
107	0210	8/18	21°00.0'	157°45.0'	79.0	04	12	81.1	75.0	1012	01	6.8	3	8	3	05	2		
108	2115	8/19	21°02.5'	157°58.5'	79.3	08	15	80.2	75.5	1014	02	8	1	8	2	12	1		
109	0240	8/20	21°17.5'	158°12.5'	81.7	25	07	82.0	76.0	1015	03	6,8	4	8	1	15	1		
110	0230	8/24	21°19.0'	158°13.0'	80.4	01	06	81.9	75.5	1012	00	6,8	5	7	2	12	1		
111	0145	8/28	20°41.5'	157°01.0'	81.0	28	06	81.1	74.0	1012	01	2,6,8	4	8	1	06	2		
112	0130	8/29	20°57.0'	158°01.0'	80.9	06	18	79.5	72.5	1013	02	2,6,8	3	8	3	10	3		

Table 6.--Summary of observations at bathythermograph lowerings, Charles H. Gilbert cruise 46
(Recording and coding of data follows U.S. Navy Hydrographic Office, 1956.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Barometer (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO4-P, (ug. at./l.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T.)	Amt.		
1	0115	9/26	21°28'	158°24'	81.0	19	05	82.1	72.9	1015	02	1,6,8	6	8	2	18	2		
	1800	9/29	21°01'	157°43'	80.8													34.78	
2	2100	9/29	20°36'	157°32'	81.4	13	10	81.9	75.9	1016	02	4,8	6	8	2	13	2	34.80	
3	0000	9/30	20°12'	157°20'	80.6	19	15	80.7	75.6	1014	02	4,8	5	8	2	19	2	34.78	
4	0300	9/30	19°48'	157°10'	80.2	08	08	79.7	74.5	1014	15	8	8	7	2	04	2	34.85	
5	0000	10/1	19°26'	157°04'	80.2	18	07	80.9	74.4	1013	01	6,8	6	7	3	12	3	34.81	
6	0300	10/1	19°04'	156°46'	79.6	14	12	80.6	74.5	1012	02	6,8	6	7	3	13	3	34.83	
7	0600	10/1	18°44'	156°29'	79.1	09	16	80.7	74.0	1014	02		8	7	3	13	3	34.86	
8	0900	10/1	18°24'	156°12'	78.5	10	18	80.0	73.3	1014	01		5	7	3	13	3	34.77	
9	1200	10/1	18°04'	155°55'	79.7	07	14	79.5	74.3	1012	01		3	7	3	06	3	34.44	
10	1500	10/1	17°44'	155°38'	80.0	C7	13	79.0	73.1	1012	02		3	7	3	10	3	34.40	
11	1800	10/1	17°33'	155°18'	80.0	06	13	80.8	74.5	1014	02	4,6,8	3	8	3	08	3	34.37	
12	2100	10/1	17°35'	155°04'	80.0	07	13	79.8	74.0	1014	01	4,8	2	8	3	08	3	34.42	
13	0000	10/2	17°29'	154°43'	80.0	04	12	79.7	74.1	1012	02	4,8	4	8	3	06	3	34.45	
14	0300	10/2	17°21'	154°21'	80.2	06	13	79.5	73.9	1012	02	4,8	4	8	3	06	3	34.51	
15	0600	10/2	17°13'	154°00'	80.0	06	10	79.8	74.4	1013	01		2	7	2	06	2	34.47	
16	0900	10/2	17°10'	153°45'	80.0	06	11	79.3	74.6	1014	02		3	7	2	06	2	34.34	
17	1200	10/2	17°07'	153°28'	80.3	06	07	79.2	73.0	1012			7	7	2	06	2	34.38	
18	1500	10/2	17°04'	153°11'	80.6	08	11	77.8	73.0	1012	20		6	7	2	09	2	34.35	
19	1645	10/2	16°57'	153°11'	80.5	07	12	80.5	73.5	1013	00	4,8	6	8	1	04	2		
20	2210	10/2	17°00'	153°15'	80.5	09	10	80.5	74.2	1013	02	4	3	8	1	09	2	34.34	
21	0035	10/3	17°06'	153°16'	80.7	06	10	80.5	74.8	1012	02	8	4	8	2	08	2		
22	0300	10/3	17°26'	153°16'	80.3	06	13	81.2	73.5	1012	02	8	4	8	2	08	2	34.40	
23	0600	10/3	17°54'	153°17'	79.5	09	10	78.1	72.9	1013	02	8	2	6	2	08	2	34.48	
24	1200	10/3	18°35'	153°11'	78.9	05	05	76.7	73.3	1014	20		7	6	1	00	2	34.70	
25	1500	10/3	19°02'	153°10'	78.7	08	06	75.5	71.0	1013	01		4	7	1	04	2	34.92	
26	1800	10/3	19°30'	153°08'	78.1	08	09	77.7	72.0	1014	18	4,6	7	6	1	04	1	34.99	
27	2100	10/3	19°57'	153°07'	78.4	10	09	77.9	72.7	1015	01	4,8	3	9	1	04	2	35.12	
28	0000	10/4	20°24'	153°06'	78.9	08	06	78.5	72.6	1013	02	8	2	9	1	03	2	35.15	
29	0300	10/4	20°51'	153°04'	78.8	07	07	78.4	71.3	1013	03	8	4	8	1	03	2	35.04	
30	0600	10/4	21°18'	153°02'	78.2	08	06	77.0	69.8	1015	02		4	9	1	03	2	35.17	
31	0900	10/4	21°36'	152°57'	78.4	09	09	77.2	70.8	1016	02		3	6	1	03	2	35.11	
32	1200	10/4	22°06'	152°55'	78.0	08	11	76.4	72.0	1015	02		3	6	1	03	2	35.17	
33	1500	10/4	22°34'	152°54'	77.9	09	08	77.0	71.5	1014	01	8	2	8	1	03	2	35.15	
34	1740	10/4	22°50'	153°00'	77.7	00	02	76.0	71.9	1015	02	8	3	8	1	03	2	35.04	
35	2200	10/4	22°50'	153°00'	77.2	10	10	78.4	72.5	1015	02	8	3	8	1	09	2		
36	0140	10/5	22°53'	152°53'	78.0	09	12	77.6	73.0	1013	03	4,8	7	8	2	09	2		
37	0600	10/5	22°48'	153°42'	78.3	13	12	78.1	73.9	1016	03		6	6	2	09	2	35.04	
38	0900	10/5	22°36'	153°54'	78.6	12	13	78.0	72.0	1016	02		6	6	2	09	2	35.03	
39	1155	10/5	22°15'	154°15'	78.4	13	13	78.3	73.8	1015	02		4	6	2	10	2	35.07	
40	1500	10/5	21°54'	154°36'	78.1	13	13	77.7	73.0	1015	01		2	8	2	10	2	35.07	

Table 6.--Summary of observations at bathythermograph lowerings, Charles H. Gilbert cruise 46 (con.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. °F.	Wind		Air temp.		Barometer (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO_4-P, (ug. at./1.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T)	Amt.		
41	1800	10/5	21°40'	154°56'	78.4	11	11	79.8	74.8	1016	03	6,8	6	7	2	13	2	35.07	
42	2100	10/5	21°25'	155°24'	79.0	13	05	78.2	74.0	1016	18	6,8	6	6	2	13	2	35.06	
43	0000	10/6	21°14'	155°50'	79.9	12	09	79.6	75.8	1014	01	8	2	8	1	13	2	34.97	
44	2100	10/8	20°54'	157°26'	80.1	12	12	80.1	73.5	1015	02	8	2	8	2	11	3	34.89	
45	2209	10/8	20°48.5'	157°33.0'	81.6										1			34.85	0.43
46	2215	10/8	20°49'	157°32'	81.8														
47	2225	10/8	20°50'	157°32'	82.0														
48	2235	10/8	20°50'	157°31'	81.9														
49	2252	10/8	20°51'	157°30'	81.4														
50	2302	10/8	20°52'	157°30'	81.3													34.89	0.47
51	2311	10/8	20°52'	157°29'	81.0														
52	2322	10/8	20°53'	157°28'	80.5														
53	2332	10/8	20°54'	157°28'	80.5													34.94	0.46
54	2342	10/8	20°54'	157°27'	79.9														
55	2352	10/8	20°55'	157°27'	79.8														
56	0002	10/9	20°55'	157°27'	79.7													34.92	
57	0012	10/9	20°56'	157°26'	80.1														
58	0022	10/9	20°56'	157°26'	80.2														
59	0032	10/9	20°57'	157°25'	80.1													34.88	0.34
60	0042	10/9	20°57'	157°25'	80.1														
61	0052	10/9	20°58'	157°24'	80.0														
62	0102	10/9	20°59'	157°24'	80.1	09	17	80.0	73.9	1012	02	8	1	8	3	09	3	34.88	
63	0600	10/9	20°21'	157°54'	80.8	13	10	81.1	74.1	1014	02		6	6	3	13	3	34.90	
64	0900	10/9	20°04'	158°04'	80.1	13	09	80.0	73.2	1016	01		2	6	2	08	3	34.77	
65	1200	10/9	19°41'	158°19'	80.0	16	12	76.5	70.8	1015	03		8	6	2	08	4	34.70	
66	1500	10/9	19°18'	158°34'	80.0	08	06	77.5	73.0	1014	02		2	7	2	09	4	34.84	
67	1800	10/9	18°59'	158°51'	80.0	09	12	80.0	74.1	1015	03	6,8	5	7	2	09	4	34.85	
68	2205	10/9	18°41'	159°14'	80.3	11	12	81.5	74.5	1015	02	8	4	7	2	09	4	34.86	
69	0000	10/10	18°28'	159°28'	80.5	11	10	81.1	73.7	1014	02	8	2	8	3	12	4	34.87	
70	0300	10/10	18°12'	159°44'	80.5	09	13	80.7	73.7	1014	02	8	2	8	3	12	4	34.81	
71	0600	10/10	17°56'	160°06'	79.6	08	15	80.0	74.2	1016	02	8	6	7	3	09	4	34.60	
72	0900	10/10	17°29'	160°06'	80.0	12	22	78.7	73.0	1016	20	8	8	5	4	08	5	34.87	
73	1200	10/10	17°00'	160°08'	80.0	12	17	80.3	74.7	1015	02	8	8	5	3	09	5	34.79	
74	1500	10/10	16°36'	160°08'	80.0	08	16	79.9	75.0	1014	01		3	6	3	09	5	34.56	
75	1720	10/10	16°26'	160°14'	80.3			80.7	76.1	1017	02	8	7	8	3			34.56	
76	2150	10/10	16°24'	160°15'	80.4	08	12	81.3	76.0	1015	02	8	7	8	3	08	4	34.44	
77	0015	10/11	16°24'	160°14'	80.8	06	16	80.2	75.7	1013	02	8	6	8	3	08	4		
78	0300	10/11	16°01'	160°14'	80.7	08	16	80.9	76.1	1012	02	8	7	8	3	10	4	34.36	
79	0600	10/11	15°33'	160°15'	80.5	08	16	81.0	76.7	1014	20	8	8	6	2	06	3	34.51	
80	0900	10/11	15°14'	160°12'	81.0	07	14	81.0	76.5	1015	01	8	4	6	2	07	3	34.46	0.47

Table 6.--Summary of observations at bathythermograph lowerings, Charles H. Gilbert cruise 46 (con.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Barometer (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO4-P, (ug. at./1.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F.)			Type	Cover			Dir. (°T.)	Amt.		
81	1200	10/11	15°32'	160°38'	80.7	07	12	80.2	77.1	1014	02	4,8	5	6	2	07	3	34.40	
82	1500	10/11	15°50'	161°02'	80.7	07	15	79.8	75.5	1014	02	6,8	5	7	2	07	3	34.51	
83	1800	10/11	16°06'	161°26'	80.0	05	14	79.5	76.0	1015	02	6,8	5	7	2	07	3	34.61	
84	2100	10/11	16°20'	161°50'	80.5	07	15	80.0	75.2	1015	02	4,6,8	5	7	2	07	3	34.79	
85	0000	10/12	16°35'	162°14'	81.0	07	17	80.4	75.4	1013	02	4,6,8	5	7	2	07	3	34.62	
86	0300	10/12	16°52'	162°39'	80.8	09	13	81.0	75.0	1012	01	8	3	8	2	06	3	34.64	
87	0600	10/12	17°06'	163°01'	80.4	08	12	80.0	74.9	1014	02	6,8	3	8	2	06	3	34.67	
88	0900	10/12	17°19'	163°09'	80.6	06	11	80.0	75.4	1016	02	8	3	7	2	06	4	34.66	
89	1200	10/12	17°42'	163°26'	80.5	05	10	79.4	73.9	1015	01	8	3	7	2	07	4	34.59	
90	1500	10/12	18°05'	163°42'	81.6	06	10	79.4	72.5	1014	02		2	7	2	07	2	34.31	
91	1800	10/12	18°28'	163°54'	81.2	09	14	80.0	73.7	1015	03	4,8	4	7	2	07	2	34.30	
92	2100	10/12	18°53'	163°58'	81.4	08	12	80.4	74.0	1013	02	4,8	4	7	2	08	2	34.64	
93	0000	10/13	18°47'	164°14'	80.6	08	09	81.6	74.0	1015	02	4,6,8	4	7	2	08	2	34.56	
94	0300	10/13	18°27'	164°36'	81.5	08	12	81.5	74.3	1013	02	4,6,8	3	7	2	08	2	34.24	
95	0600	10/13	18°08'	164°57'	81.3	06	13	80.9	74.8	1015	02	4,8	3	7	2	09	2	34.31	
96	0900	10/13	17°54'	165°07'	81.6	07	16	80.8	75.3	1016	03	4,8	5	7	2	09	2	34.32	
97	1200	10/13	17°34'	165°27'	81.8	08	14	80.5	75.2	1014	02	8	4	7	2	08	2	34.33	
98	1500	10/13	17°14'	165°47'	81.4	08	15	80.2	74.5	1013	02		4	7	2	08	2	34.36	
99	1800	10/13	16°53'	166°08'	80.8	10	12	80.0	74.8	1014	18	6,8	6	6	3	08	3	34.45	
100	2100	10/13	16°34'	166°30'	80.0	09	14	82.2	74.8	1015	01	6,8	5	7	2	10	3	34.67	0.51
101	0000	10/14	16°58'	166°43'	81.6	09	11	81.0	74.9	1013	02	4,8	4	7	2	09	3	34.46	
102	0300	10/14	17°23'	166°55'	81.5	08	10	79.7	75.5		21	8	7	7	2	08	3	34.41	
103	0600	10/14	17°47'	167°08'	81.3	10	15	80.8	76.1	1014	03	6,8	6	6	2	08	3	34.68	
104	0900	10/14	18°16'	167°12'	81.3	05	14	80.5	76.0	1015	01	6,8	4	6	2	07	5	34.58	
105	1200	10/14	18°45'	167°15'	81.7	04	10	80.1	74.3	1014	02	8	3	7	2	04	5	34.58	
106	1500	10/14	19°13'	167°19'	81.5	06	15	79.7	75.2	1013	01	8	2	7	2	04	5	34.66	
107	1800	10/14	19°37'	167°29'	81.1	04	17	80.0	75.1	1014	03	4,6,8	4	7	2	04	5	34.97	
108	2100	10/14	19°59'	167°17'	81.0	07	12	81.0	74.8	1015	02	6,8	4	7	2	05	4	35.09	
109	0000	10/15	20°22'	167°01'	81.3	06	13	81.4	75.0	1014	02	8	2	8	3	06	4	35.10	
110	0300	10/15	20°45'	166°48'	81.2	06	12	80.8	73.8	1012	02	6,8	2	8	3	06	4	35.10	0.13
111	0600	10/15	20°42'	166°19'	81.5	07	13	78.7	73.4	1014	03	6,8	5	8	2	06	4	34.74	
112	0900	10/15	20°38'	165°59'	81.8	07	14	80.9	74.7	1015	03	4,8	6	8	3	07	3	34.60	
113	1200	10/15	20°33'	165°32'	81.4	07	14	80.3	74.5	1014	03	6,8	6	7	3	07	3	34.77	
114	1500	10/15	20°27'	165°02'	81.0	07	11	80.0	74.5	1013	02	4,8	5	7	2	07	3	34.68	
115	1800	10/15	20°21'	164°31'	81.3	06	12	81.5	74.0	1014	01	4,6,8	3	7	2	07	3	34.74	
116	2100	10/15	20°13'	164°02'	81.4	04	09	81.1	73.8	1015	02	4,8	2	8	2	09	3	34.98	
117	0000	10/16	20°28'	163°42'	81.4	04	12	81.6	75.0	1013	03	4,8	7	8	2	05	3	34.84	
118	0300	10/16	20°49'	163°26'	81.5	07	10	81.4	75.9	1013	02	4,8	7	8	2	06	3	34.77	
119	0600	10/16	21°10'	163°09'	81.2	09	12	80.5	75.2	1014	02	4,8	5	6	2	06	3	34.78	
120	0900	10/16	21°24'	162°57'	81.3	08	12	80.2	74.8	1016	01	4,8	4	6	2	06	3	34.82	

Table 6.--Summary of observations at bathythermograph lowerings, Charles H. Gilbert cruise 46 (con.)

Ser. No.	Time (GCT)	Date, 1959	Latitude N.	Longitude W.	Bkt. temp. (°F.)	Wind		Air temp.		Barometer (mb.)	Weather	Clouds		Visibility	Sea	Swell		Surf. sal. (‰)	Surf. PO_4-P, (ug. at./1.)
						Dir. (°T.)	Force (kn.)	Dry bulb (°F.)	Wet bulb (°F)			Type	Cover			Dir. (°T.)	Amt.		
121	1200	10/16	21°46'	162°42'	81.1	07	14	80.3	74.0	1015	01	8	2	7	2	06	3	34.74	
122	1500	10/16	22°08'	162°26'	80.8	08	13	79.5	73.5	1015	02	8	2	7	2	06	3	34.73	
123	1800	10/16	22°30'	162°12'	79.7	08	12	80.0	74.8	1016	02	6,8	2	7	2	06	3	35.17	
124	2100	10/16	22°54'	161°58'	79.9	10	16	80.3	73.5	1017	02	4,8	2	7	3	07	3	35.01	
125	0300	10/17	22°31'	161°45'	79.8	08	12	80.4	73.2	1015	02	8	3	7	3	08	3	34.97	
126	0600	10/17	22°04'	161°35'	80.5	07	14	79.8	73.3	1016	02	8	3	7	3	10	4	34.86	
127	0900	10/17	21°35'	161°25'	81.0	09	15	79.9	73.7	1016	03	8	6	7	4	11	4	34.72	
128	1100	10/17	21°17'	161°18'	80.6	09	16	79.7	71.8	1015	01	8	3	7	3	10	4	34.71	
129	1500	10/17	21°32'	160°45'	80.5	10	17	79.2	71.5	1015	02	8	2	7	3	10	4	34.80	
130	1800	10/17	21°42'	160°22'	80.5	08	18	79.5	72.8	1016	02	8	3	8	3	10	4	34.70	
131	2100	10/17	21°58'	160°02'	80.8	11	11	79.6	74.0	1017	02	8	1	8	2	09	1	34.74	
132	0300	10/18	22°28'	159°40'	80.1	09	18	79.8	74.5	1016	02	8	1	7	3	09	4	34.88	
133	0600	10/18	22°51'	159°32'	79.9	10	14	80.2	74.2	1018	03	6,8	4	7	2	08	4	34.95	0.20
134	1200	10/18	22°27'	159°06'	79.4	08	12	78.3	72.1	1018	02	8	3	7	3	11	4	34.96	
135	1500	10/18	22°06'	158°48'	79.6	10	17	77.7	71.5	1017	02	8	2	7	3	11	4	34.98	
136	1800	10/18	21°46'	158°30'	79.0	08	16	78.3	70.6	1018	03	8	4	7	3	11	4	35.00	

Table 7.--Summary of weather observations (USWB 1210-F), Hugh M. Smith cruise 50[1/]

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. corr. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
1/11	18.1°	155.2°	0000	99	15	04	02	1	1011.5	7	2.0	79.4	73.6	78.1	3	1	4	7	8	0	15	4	3
1/11	17.4°	154.6°	0600	99	11	07	02	0	1012.9	2	0.9	76.7	73.5	76.9	2	2	4	X	X	X	15	4	3
1/11	16.9°	154.1°	1200	99	08	10	02	0	1011.9	7	1.5	76.8	73.2	77.8	1	1	X	X	X	X	15	4	4
1/11	16.1°	153.5°	1800	99	11	12	15	2	1013.2	2	0.6	78.0	73.7	77.3	7	2	4	7	8	0	11	4	4
1/12	15.4°	152.9°	0000	99	08	14	03	2	1009.5	6	2.3	78.0	73.9	77.0	7	6	8	6	3	X	11	4	4
1/12	14.7°	152.4°	0600	99	08	14	02	2	1011.5	2	1.0	77.3	74.0	77.0	7	X	X	X	X	X	11	4	4
1/12	14.0°	151.9°	1200	99	08	14	02	0	1010.2	8	1.5	78.0	74.2	77.9	1	1	X	X	X	X	11	4	4
1/12	13.5°	151.3°	1800	99	09	18	02	2	1009.8	2	1.5	79.0	74.5	78.2	5	4	4	6	6	0	11	4	4
1/13	12.9°	150.8°	0000	99	11	21	02	1	1006.4	7	2.7	79.2	74.8	78.6	3	3	4	6	6	0	11	4	5
1/13	12.7°	150.3°	0600	99	12	16	03	1	1008.5	2	1.9	79.4	74.8	78.9	4	X	X	X	X	X	11	4	5
1/13	12.7°	149.9°	1200	99	12	20	02	2	1008.1	8	0.8	79.3	72.9	78.1	6	X	X	X	X	X	11	4	5
1/13	12.8°	149.6°	1800	99	12	19	02	0	1010.2	2	0.5	80.5	74.7	78.2	2	2	4	6	0	0	11	4	5
1/14	13.5°	149.6°	0600	99	11	14	02	0	1010.8	2	2.6	78.5	73.5	78.1	2	X	X	X	X	X	11	4	5
1/14	14.5°	149.6°	1200	99	10	13	02	0	1009.8	7	0.2	78.0	74.4	78.0	2	X	X	X	X	X	11	4	5
1/14	15.1°	149.6°	1800	98	85	13	14	2	1013.9	2	3.2	78.2	75.0	77.7	8	8	8	5	X	X	90	4	5
1/15	15.7°	149.3°	0600	99	10	14	02	2	1013.2	2	1.6	78.1	75.5	77.8	7	7	X	X	X	X	90	4	5
1/15	16.5°	149.1°	1200	99	13	14	02	2	1011.5	8	1.3	77.7	75.0	77.3	4	X	X	X	X	X	10	3	2
1/16	17.3°	148.6°	0600	99	21	10	80	2	1011.5	2	1.7	78.1	75.1	77.5	8	X	X	X	X	X	10	3	2
1/16	17.1°	148.2°	1200	99	03	14	02	2	1010.2	7	1.5	75.0	71.5	77.0	5	X	X	X	X	X	08	3	2
1/17	17.3°	147.2°	0600	99	13	14	01	1	1009.1	2	1.9	76.4	72.1	76.5	2	2	1	0	0	0	31	3	4

[1/] All columns in USWB 1210-F are not included here. Those deleted are:

Column	2	Day of week
"	3	Octant
"	13	Barometer as read
"	14	Barometer as corrected
"	17	Air temperature, °F.
"	23	Course of ship
"	24	Speed of ship
"	31	Diff. sea-air, °F.
"	32	Dew point, °F.

Table 7.--Summary of weather observations (USWB 1210-F), Hugh M. Smith cruise 50 (con.)

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. corr. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
1/17	18.1°	147.3°	1200	99	14	17	02	0	1007.8	7	2.0	76.2	72.0	77.2	2	X	X	X	X	X	12	2	4
1/17	18.9°	147.5°	1800	99	15	20	02	1	1010.8	2	0.9	76.8	70.0	77.1	7	6	8	6	4	0	15	4	4
1/18	19.6°	148.2°	0000	99	15	23	02	2	1001.8	6	2.0	77.2	71.1	76.5	5	1	4	6	4	0	15	3	6
1/18	20.3°	148.9°	0600	99	16	23	02	1	1009.5	0	1.2	76.9	72.0	76.1	4	X	X	X	X	X	15	3	6
1/18	20.9°	149.6°	1200	99	16	28	02	1	1008.8	7	0.8	76.4	72.5	75.4	4	X	X	X	X	X	15	3	6
1/18	21.8°	150.1°	1800	99	16	30	14	2	1007.8	5	0.3	77.9	72.9	74.4	6	6	8	6	4	0	15	3	6
1/19	21.4°	149.6°	0600	98	16	24	02	2	1012.5	2	2.5	76.9	73.7	76.0	8	X	X	X	X	X	15	3	7
1/19	20.4°	149.2°	1800	99	16	24	02	2	1014.6	0	0.2	76.2	73.2	76.0	7	4	8	8	7	X	15	3	4
1/20	22.0°	150.1°	0000	97	11	18	63	2	1013.2	7	2.2	75.9	74.0	76.0	8	7	6	7	X	X	25	5	6
1/20	21.8°	148.9°	0600	98	15	18	60	2	1015.6	2	0.8	75.4	72.6	74.8	8	X	X	X	X	X	15	3	5
1/20	21.8°	148.5°	1200	99	16	10	02	2	1015.9	6	0.7	74.7	71.7	74.4	5	X	X	X	X	X	15	3	5
1/20	21.2°	147.8°	1800	99	05	14	14	6	1017.6	1	0.9	72.6	67.9	74.3	7	7	8	6	4	X	05	2	3
1/21	21.3°	148.0°	0600	99	14	10	03	1	1015.6	2	1.2	74.9	71.1	74.7	6	X	X	X	5	X	14	3	3
1/21	22.2°	148.0°	1200	99	14	10	02	0	1014.2	7	0.4	74.0	70.4	74.5	4	4	2	6	0	0	09	3	3
1/21	23.0°	148.0°	1800	99	19	14	14	2	1014.9	2	1.5	74.9	70.2	73.3	7	4	8	5	5	0	15	3	3
1/22	23.2°	148.4°	0600	99	16	08	02	2	1014.6	2	1.1	72.7	70.1	73.0	7	X	8	6	X	X	09	3	3
1/22	23.2°	149.1°	1200	99	16	07	14	8	1013.9	7	1.0	71.7	68.2	73.5	8	X	8	6	X	X	26	4	4
1/23	23.3°	149.5°	0600	98	26	12	14	8	1018.0	2	2.1	72.1	67.4	74.0	8	X	8	5	X	X	32	4	3
1/23	22.6°	150.1°	1200	99	33	14	02	0	1018.0	8	0.3	73.0	70.0	74.6	3	3	2	5	0	0	24	3	2
1/23	21.6°	150.4°	1800	99	03	13	02	0	1020.0	2	1.3	73.9	67.7	75.1	2	2	2	5	0	0	34	3	4
1/24	20.9°	150.9°	0000	99	04	18	02	0	1018.6	7	1.9	74.6	67.9	74.9	3	3	2	5	0	0	34	4	5
1/24	20.0°	151.5°	0600	99	04	26	02	0	1021.3	2	1.9	73.9	67.9	76.0	2	2	2	5	0	0	34	4	5
1/24	19.3°	150.0°	1200	98	06	22	03	1	1020.7	7	1.2	74.5	69.5	76.3	7	7	8	6	0	0	05	4	5
1/24	18.4°	152.6°	1800	96	05	22	80	2	1021.7	3	1.6	74.8	70.8	76.7	8	8	6	5	X	X	05	3	4
1/25	19.1°	153.1°	0000	98	08	22	02	1	1019.6	7	1.7	77.0	72.0	76.9	7	7	8	6	0	0	05	3	4
1/25	19.9°	153.8°	0600	99	07	20	15	2	1021.0	2	1.5	75.0	70.0	76.3	6	6	8	6	0	0	06	3	4
1/25	20.5°	154.2°	1200	97	09	18	02	2	1021.0	6	0.6	74.1	70.0	75.3	6	5	8	6	X	0	07	3	4
1/25	21.3°	154.8°	1800	99	09	17	02	1	1022.0	2	1.5	76.0	71.0	74.1	2	2	8	6	0	0	07	3	4
1/26	22.2°	155.1°	0000	99	10	17	16	2	1020.0	7	2.7	74.2	70.4	74.1	7	7	8	6	0	0	10	3	3
1/26	22.9°	154.5°	0600	98	11	12	14	6	1022.0	2	1.2	73.5	70.4	73.8	7	7	8	6	X	X	09	3	3
1/26	22.9°	154.2°	1200	99	11	14	01	1	1021.7	7	0.9	73.1	70.0	73.0	3	3	8	6	0	0	09	3	3
1/26	22.8°	153.0°	1800	98	11	16	15	1	1023.0	2	1.9	71.2	67.5	73.0	4	4	8	6	0	0	09	3	3
1/27	22.0°	153.2°	0600	99	11	15	02	0	1019.6	2	0.7	73.2	68.4	74.0	2	X	2	X	X	X	12	3	5
1/27	21.4°	153.6°	1200	99	10	19	02	1	1018.0	7	1.5	74.9	68.7	74.9	4	3	8	6	6	0	12	3	4
1/27	20.8°	154.4°	1800	99	13	17	02	0	1018.6	2	1.8	76.5	69.4	74.1	2	1	2	6	4	0	12	4	6

Table 7.--Summary of weather observations (USWB 1210-F), Hugh M. Smith cruise 50 (con.)

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. corr. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
1/28	20.1°	154.9°	0000	99	13	14	03	1	1014.9	7	3.0	76.8	70.1	76.1	4	4	8	6	4	0	12	4	6
1/29	18.7°	155.7°	0000	99	07	18	02	0	1015.2	7	3.1	77.0	71.5	77.5	2	2	2	6	0	0	12	4	5
1/29	18.1°	156.6°	0600	99	10	18	02	0	1016.9	2	1.1	76.7	71.6	77.3	1	2	2	6	0	0	10	4	5
1/29	17.5°	155.2°	1200	99	09	19	02	0	1015.6	7	0.7	76.7	71.0	77.5	3	3	2	6	X	X	09	4	3
1/29	16.9°	158.0°	1800	99	08	21	02	1	1016.6	2	1.2	77.2	72.0	78.0	6	6	2	6	0	0	08	4	4
1/30	17.5°	158.7°	0000	99	09	18	02	1	1013.9	7	2.6	77.2	71.3	77.6	4	4	2	6	0	0	08	4	4
1/30	18.2°	159.5°	0600	99	08	14	02	1	1016.6	2	2.0	76.9	71.6	77.4	3	3	2	6	0	0	08	4	4
1/30	18.6°	160.0°	1200	99	06	10	02	0	1016.6	7	1.0	75.0	70.5	75.6	2	2	2	6	0	0	11	4	4
1/30	19.3°	160.8°	1800	99	05	06	02	0	1017.6	2	1.6	74.9	69.5	75.5	3	3	8	6	6	0	11	4	3
1/31	19.9°	161.7°	0000	99	03	06	02	0	1015.6	7	2.7	76.5	69.4	77.4	1	1	1	5	0	0	11	4	4
1/31	20.5°	162.3°	0600	99	01	12	02	0	1017.6	2	2.0	76.7	69.0	76.1	3	3	8	5	0	0	11	4	3
1/31	21.1°	162.4°	1200	99	03	22	03	1	1018.0	4	0.0	73.0	68.8	75.4	6	6	X	X	X	X	11	4	3
2/1	22.1°	162.7°	0000	99	05	23	02	2	1019.6	7	2.1	70.0	62.5	75.0	7	7	8	6	X	X	03	3	6
2/1	22.6°	162.7°	0600	99	06	27	02	2	1023.0	2	2.0	69.0	60.8	73.8	7	X	X	X	X	X	03	3	6
2/1	21.8°	163.5°	1200	98	07	26	01	1	1022.7	7	1.5	69.1	64.2	74.9	2	X	X	X	X	X	07	3	5
2/1	21.2°	164.0°	1800	99	06	25	15	1	1022.0	3	0.5	68.5	64.9	74.5	5	5	8	6	0	0	07	3	6
2/2	20.6°	164.7°	0000	99	08	20	02	0	1020.3	7	2.3	72.1	66.8	75.4	4	4	8	6	0	0	07	3	6
2/2	20.0°	165.2°	0600	99	09	23	02	1	1019.3	2	0.5	73.1	67.9	75.5	3	3	8	6	0	0	08	3	5
2/2	19.0°	165.3°	1200	99	08	16	02	0	1019.0	7	1.8	74.5	68.0	75.0	3	X	X	X	X	X	08	3	5
2/3	18.2°	166.0°	0600	99	07	16	02	1	1016.9	2	0.9	75.2	66.0	74.9	7	7	8	6	X	X	08	3	5
2/3	17.4°	166.2°	1200	XX	09	23	02	2	1015.9	7	1.6	75.4	66.9	77.3	8	X	X	X	X	X	08	3	6
2/3	16.6°	166.3°	1800	98	07	20	02	2	1015.6	3	0.5	76.5	66.8	77.6	7	7	8	6	0	0	08	3	6
2/4	16.4°	167.2°	0000	99	08	22	01	1	1014.6	7	1.9	77.4	67.5	77.6	2	2	8	6	0	0	07	3	6
2/4	16.4°	168.2°	0600	99	08	21	02	1	1013.5	3	0.4	76.8	69.0	77.5	3	3	8	6	0	0	07	3	6
2/4	16.4°	169.2°	1200	99	08	22	02	0	1013.9	8	1.4	76.0	69.0	76.2	2	X	X	X	X	X	07	3	6
2/5	16.4°	170.7°	0000	99	07	23	02	0	1012.5	8	1.2	76.1	69.3	76.8	4	4	8	5	0	0	06	4	7
2/5	16.0°	170.0°	0600	99	07	16	02	1	1010.8	4	0.0	75.0	69.0	76.6	4	4	8	6	0	0	06	4	6
2/5	15.5°	169.3°	1200	99	08	16	02	0	1010.8	8	1.0	76.0	69.6	77.1	3	X	X	X	X	X	06	4	6
2/5	15.0°	168.7°	1800	99	09	14	14	1	1010.2	3	0.8	76.5	69.2	77.4	3	2	8	5	4	0	08	3	5
2/6	14.7°	168.0°	0000	99	08	19	02	1	1009.5	7	2.0	76.5	71.2	77.9	4	4	8	6	0	0	08	3	6
2/6	14.3°	167.3°	0600	99	07	20	02	1	1008.8	2	1.0	77.0	71.9	78.0	5	5	8	6	0	0	08	3	6
2/6	13.9°	166.5°	1200	98	07	20	14	2	1009.5	7	1.0	76.0	72.8	78.0	7	X	X	X	X	X	08	3	6
2/6	13.6°	165.8°	1800	99	06	20	15	2	1009.5	3	1.8	77.5	72.8	78.2	7	6	8	6	4	0	08	3	6
2/7	13.1°	165.3°	0000	98	06	20	02	2	1007.8	7	2.8	78.6	74.0	78.6	8	8	8	6	0	0	08	3	6
2/7	13.6°	164.9°	0600	98	05	22	14	8	1008.5	2	0.9	77.1	73.8	78.5	8	X	X	X	X	X	06	3	6

Table 7.--Summary of weather observations (USWB 1210-F), Hugh M. Smith cruise 50 (con.)

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. corr. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
2/7	14.5°	164.3°	1800	98	06	21	02	2	1008.8	2	1.3	77.5	73.5	78.1	7	7	8	6	0	0	06	3	6
2/8	15.5°	163.3°	0600	99	06	22	14	8	1009.1	2	1.8	76.0	73.2	76.9	7	7	8	6	0	0	06	3	6
2/8	16.5°	162.1°	1800	98	06	13	14	2	1010.2	2	1.6	76.0	72.9	76.3	8	8	8	6	0	0	06	3	4
2/9	17.2°	161.6°	0000	96	09	09	14	2	1009.8	8	1.0	76.8	74.5	76.5	8	8	6	4	X	X	09	3	4
2/9	17.8°	161.1°	0600	96	11	17	14	8	1010.8	2	1.0	75.5	71.9	76.7	7	7	6	4	X	X	09	3	4
2/9	18.4°	160.5°	1200	98	13	18	14	2	1011.2	1	0.8	77.0	73.9	75.0	8	X	X	X	X	X	09	3	4
2/9	19.0°	160.0°	1800	96	11	14	61	6	1012.5	2	1.6	76.1	73.6	76.3	8	8	6	4	X	X	12	3	3
2/10	19.7°	159.5°	0600	96	11	10	61	6	1014.2	2	2.2	74.6	71.0	76.2	8	X	X	X	X	X	10	3	3
2/10	20.3°	158.9°	1200	XX	14	08	60	6	1013.2	7	1.4	74.1	71.1	76.1	8	8	X	X	X	X	10	3	3

Table 8.--Summary of weather observations (USWB 1210-F), Hugh M. Smith cruise 51[1]

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. corr. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
3/4	21.1°	157.5°	0600	99	09	17	00	0	1017.6	1	1.0	75.0	68.3	75.1	1	1	1	5	0	0	XX	X	X
3/6	21.2°	156.3°	0000	98	08	20	00	0	1018.6	6	1.5	75.7	68.3	74.8	4	4	1	5	0	0	07	3	5
3/6	21.8°	156.2°	0600	97	08	20	00	1	1020.7	2	1.5	73.2	67.3	74.7	6	6	1	5	0	0	XX	X	X
3/6	22.2°	155.9°	1200	97	06	24	00	X	1021.3	8	1.0	72.0	66.8	72.8	X	5	X	X	X	X	07	3	7
3/6	22.8°	155.6°	1800	98	08	20	03	2	1022.7	2	1.5	71.8	64.1	73.2	7	7	1	5	0	0	06	3	6
3/7	23.3°	155.3°	0000	98	08	23	01	2	1021.7	7	2.8	74.0	65.6	72.8	2	2	1	5	0	0	07	3	6
3/7	23.9°	155.0°	0600	98	08	22	02	0	1023.7	1	2.0	72.3	65.5	72.7	3	3	1	5	0	0	06	3	6
3/7	23.9°	154.0°	1800	98	10	22	02	1	1023.4	2	1.5	71.9	61.6	71.3	6	6	1	5	0	0	08	3	6
3/8	24.0°	153.5°	0000	98	09	18	02	5	1021.3	7	2.1	72.0	65.3	70.9	6	6	1	5	0	0	08	3	5
3/8	23.9°	152.8°	0600	98	09	18	02	2	1022.7	2	1.2	71.4	64.0	70.3	5	5	1	5	0	0	08	3	5
3/8	23.9°	152.2°	1200	98	09	20	00	X	1022.0	7	1.0	69.5	64.5	70.2	6	X	X	X	X	X	08	3	6
3/8	23.9°	151.8°	1800	98	10	16	15	2	1022.7	3	1.0	71.6	61.9	70.8	7	7	4	5	0	0	09	3	5
3/9	24.0°	151.3°	0000	97	10	21	02	2	1021.3	7	2.1	69.7	64.0	72.5	8	8	8	5	0	0	08	3	5
3/9	24.0°	150.8°	0600	97	10	20	02	2	1022.0	2	1.1	71.2	64.0	71.0	8	8	8	5	0	0	08	3	5
3/9	24.0°	150.1°	1200	97	10	24	00	2	1021.3	7	1.3	71.0	62.3	70.9	8	8	8	5	0	0	08	3	6
3/9	24.0°	149.7°	1800	98	10	22	02	2	1022.7	3	1.7	70.9	64.0	71.3	7	7	4	5	0	0	08	3	6
3/10	24.0°	149.2°	0000	98	09	18	01	2	1021.3	7	2.4	72.2	66.0	72.5	3	3	1	5	0	0	08	3	6
3/10	24.0°	148.6°	0600	98	09	20	03	1	1022.7	2	1.4	70.9	65.0	71.8	7	7	7	5	0	0	08	3	6
3/10	24.0°	147.9°	1200	98	09	20	01	1	1022.0	7	1.4	70.6	62.5	70.5	2	2	1	5	0	0	08	3	6
3/10	24.0°	147.5°	1800	98	09	27	15	0	1022.0	2	0.5	70.6	62.0	71.7	4	4	1	5	0	0	08	3	6

[1] All columns in USWB 1210-F are not included here. Those deleted are:

Column	2	Day of week
"	3	Octant
"	13	Barometer as read
"	14	Barometer as corrected
"	17	Air temperature, °F.
"	23	Course of ship
"	24	Speed of ship
"	31	Diff. sea-air, °F.
"	32	Dew point, °F.

Table 8.--Summary of weather observations (USWB 1210-F), Hugh M. Smith cruise 51 (con.)

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. corr. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
3/11	24.0°	147.0°	0000	98	09	23	03	1	1020.0	7	1.9	70.9	63.0	71.1	5	5	1	5	0	0	08	3	6
3/11	24.0°	146.5°	0600	98	09	22	02	1	1022.0	2	1.2	70.2	63.0	71.0	5	5	7	5	0	0	08	3	7
3/11			1200	98	09	23	01	1	1020.0	8	1.0	69.7	62.4	70.5	2	2	1	5	0	0	08	3	8
3/11	23.9°	145.5°	1800	98	08	22	25	1	1022.4	3	1.9	70.2	63.7	70.5	8	8	6	6	0	0	07	3	6
3/12	23.6°	145.1°	0000	98	06	28	02	2	1020.7	7	2.0	70.1	64.7	70.1	8	8	7	5	0	0	06	4	8
3/12	22.8°	145.6°	0600	98	07	26	02	2	1021.7	2	1.6	70.7	64.5	71.8	5	5	7	5	0	0	06	4	8
3/12	22.1°	146.1°	1200	98	07	26	01	1	1020.0	7	1.7	72.0	67.0	72.5	2	2	7	5	0	0	06	4	8
3/12	21.4°	146.2°	1800	98	07	23	02	1	1020.0	0	1.0	72.0	67.4	72.4	6	6	1	5	0	0	06	4	7
3/13	20.7°	146.6°	0000	98	07	24	50	1	1016.6	7	2.8	71.9	68.8	73.0	8	8	1	5	0	0	06	4	8
3/13	19.8°	146.9°	0600	97	08	22	80	2	1017.6	2	1.5	72.9	69.1	73.0	8	8	1	5	0	0	06	4	7
3/13	19.3°	147.1°	1200	97	09	15	51	6	1015.9	7	2.3	71.9	70.2	73.1	8	8	7	4	0	0	06	4	7
3/13	18.3°	147.5°	1800	98	09	18	03	8	1015.6	1	0.4	74.1	69.8	75.0	7	7	7	4	0	0	06	4	4
3/14	17.7°	147.7°	0600	98	11	10	02	0	1014.2	1	1.5	76.2	71.2	74.9	2	2	1	5	0	0	XX	X	2
3/14	17.0°	148.0°	1200	98	10	05	02	0	1014.2	7	1.5	75.0	71.0	75.2	1	2	1	5	0	0	07	5	3
3/14	16.0°	148.5°	1800	98	13	06	02	0	1014.6	2	0.7	77.1	71.4	75.4	1	1	1	5	4	0	06	3	2
3/15	15.2°	148.7°	0000	98	07	06	03	1	1012.9	7	2.1	77.5	71.7	78.0	6	3	8	6	9	9	07	4	3
3/15	14.3°	149.0°	0600	98	05	06	02	2	1014.2	1	0.8	77.9	72.8	77.0	6	3	8	6	X	X	07	4	3
3/15	15.0°	149.7°	1200	98	04	10	01	1	1013.9	8	1.0	76.9	72.0	76.9	2	2	1	5	0	0	08	5	3
3/15	14.8°	150.2°	1800	98	06	15	02	0	1015.9	1	1.4	76.8	72.0	76.9	2	2	1	5	0	0	03	4	3
3/16	15.3°	150.8°	0600	98	06	15	02	0	1017.6	2	3.0	77.7	72.4	76.8	0	0	0	9	4	0	06	4	2
3/16	15.9°	151.4°	1200	98	06	15	03	0	1018.0	7	1.1	76.0	71.8	76.1	2	2	1	5	0	0	06	4	2
3/16	16.6°	152.0°	1800	98	04	16	02	0	1020.3	2	2.0	77.1	71.0	76.3	2	2	1	5	0	0	03	2	3
3/17	17.5°	152.5°	0000	98	04	18	03	0	1018.3	7	2.0	77.4	71.3	76.0	4	4	1	5	0	0	03	2	4
3/17	18.3°	153.2°	0600	98	05	21	02	0	1020.3	2	1.8	75.2	70.0	75.1	3	3	1	5	0	0	03	2	5
3/17	19.0°	153.5°	1200	98	05	17	02	0	1021.3	7	1.3	74.5	69.4	74.9	2	2	1	5	0	0	03	2	5
3/17	19.9°	153.6°	1800	98	06	18	02	0	1023.4	2	2.2	74.3	69.0	73.9	3	3	1	5	0	0	03	2	4
3/18	20.7°	153.7°	0000	98	04	14	02	0	1021.7	7	1.6	74.5	67.8	74.5	3	3	1	5	0	0	03	2	5
3/18	21.6°	153.8°	0600	97	05	20	02	1	1022.4	2	1.6	74.0	69.1	73.2	6	6	1	5	0	0	03	2	5
3/18	22.4°	153.9°	1200	98	05	16	02	1	1022.7	8	0.5	73.5	70.0	72.6	5	5	1	5	0	0	03	2	5
3/18	22.9°	154.2°	1800	98	05	13	02	1	1023.0	2	1.5	73.8	69.6	72.7	6	6	1	5	0	0	03	2	5
3/19	22.5°	155.0°	0000	98	07	09	02	2	1021.3	7	1.7	76.0	70.7	75.2	6	6	1	5	0	0	07	6	3
3/19	22.0°	155.9°	0600	98	06	17	02	0	1022.0	1	0.7	75.0	69.6	74.9	2	2	1	5	0	0	07	X	3
3/19	21.7°	156.6°	1200	98	08	19	02	0	1021.3	7	0.6	74.1	70.1	74.0	2	2	1	5	0	0	07	6	3
3/22	21.3°	158.5°	0000	99	10	13	02	0	1020.3	7	2.5	79.5	69.5	75.6	1	1	1	5	0	0	07	3	2
3/22	21.7°	159.3°	0600	98	06	22	00	1	1021.7	1	1.7	76.3	70.0	75.8	6	6	1	5	0	0	07	3	2

Table 8.--Summary of weather observations (USWB 1210-F), Hugh M. Smith cruise 51 (con.)

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. corr. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
3/22	22.1°	160.2°	1200	98	06	19	02	1	1021.0	7	1.2	75.0	70.0	75.0	4	1	1	5	1	0	06	3	4
3/22	22.6°	161.1°	1800	98	08	17	00	1	1021.3	1	1.3	75.4	69.8	74.0	6	6	1	5	0	0	05	3	4
3/23	22.9°	161.7°	0000	98	13	15	02	1	1018.6	7	2.0	76.0	69.5	74.2	2	2	1	5	0	0	12	3	4
3/23	22.1°	161.5°	0600	98	16	06	02	0	1018.6	3	0.5	75.2	68.6	74.2	1	1	1	5	0	0	12	3	4
3/23	21.3°	161.3°	1200	98	16	07	00	0	1018.3	7	1.1	75.0	69.0	75.8	0	0	0	0	0	0	12	3	4
3/23	20.5°	161.1°	1800	98	09	12	03	1	1019.3	1	1.4	75.5	70.2	75.3	6	6	4	5	0	0	06	3	3
3/24	20.0°	160.9°	0600	98	11	11	01	1	1018.6	2	1.2	76.4	70.3	76.5	1	1	1	5	0	0	12	3	3
3/24	19.1°	160.6°	1200	98	11	10	02	0	1020.0	8	0.4	76.2	70.6	76.6	0	0	0	0	0	0	11	3	4
3/24	18.2°	160.4°	1300	98	09	18	15	1	1020.0	2	2.0	76.4	71.5	76.9	6	6	4	5	0	0	11	3	4
3/25	18.3°	159.7°	0000	98	09	19	02	2	1018.6	7	1.6	77.9	70.0	77.0	6	2	1	5	4	0	09	3	6
3/25	18.8°	159.2°	0600	98	07	14	02	1	1019.6	1	1.3	77.1	70.3	76.1	2	2	1	5	0	0	09	3	6
3/25	19.3°	158.6°	1200	98	09	16	03	0	1020.3	6	0.6	75.8	71.0	76.1	4	4	1	5	0	0	09	3	7
3/25	20.0°	157.8°	1800	98	07	17	80	2	1021.0	0	0.6	74.9	70.6	75.1	6	6	4	5	0	0	07	3	8
3/26	20.3°	157.3°	0000	98	08	24	03	1	1020.0	7	2.0	77.5	71.8	75.0	4	2	1	5	9	0	07	3	8
3/26	21.5°	155.7°	1800	98	10	26	15	2	1023.0	1	1.8	74.0	70.4	74.0	7	7	4	5	0	0	08	3	7
3/27	22.1°	155.3°	0000	98	11	26	03	1	1022.0	7	1.5	77.0	70.2	74.8	7	7	7	5	0	0	10	3	8
3/27	22.6°	154.6°	0600	98	10	26	02	1	1023.0	2	1.5	75.6	68.7	74.5	2	2	7	5	0	0	09	3	8
3/27	22.7°	154.2°	1200	98	10	20	02	2	1023.7	8	1.0	73.8	67.0	72.0	7	7	7	5	0	0	09	3	8
3/27	23.3°	153.1°	1800	98	11	18	15	2	1025.7	2	1.4	74.4	67.4	72.9	7	7	4	5	0	0	09	3	6
3/28	23.7°	152.5°	0000	98	12	22	01	1	1024.7	7	2.0	75.2	66.5	72.6	1	1	1	5	0	0	09	3	7
3/28	24.2°	151.5°	0600	98	10	18	02	0	1025.7	2	2.3	73.9	66.5	73.8	1	1	1	5	0	0	09	3	5
3/28	24.2°	150.9°	1200	98	10	20	03	1	1025.4	7	1.6	70.5	67.0	72.9	6	6	7	5	0	0	09	3	6
3/28	24.2°	150.0°	1800	98	09	22	02	0	1025.4	3	1.0	71.8	64.4	71.7	2	2	1	5	0	0	09	3	6
3/29	24.1°	149.3°	0000	98	11	21	01	0	1023.0	7	2.0	72.1	64.3	72.0	1	1	1	5	0	0	10	3	7
3/29	24.1°	148.8°	0600	98	08	19	02	1	1025.1	1	1.8	72.5	65.5	71.7	6	6	1	5	0	0	10	3	5
3/29	24.0°	148.1°	1200	98	10	23	02	2	1024.4	7	1.5	71.6	64.5	71.9	6	3	1	5	3	0	10	3	6
3/29	23.7°	147.6°	1800	98	10	20	15	2	1025.4	2	1.4	71.9	64.8	71.6	5	5	4	5	0	0	09	3	6
3/30	23.1°	147.2°	0000	98	08	20	21	2	1022.7	7	2.5	71.0	65.5	71.4	6	5	7	5	0	0	09	3	8
3/30	22.5°	146.7°	0600	98	09	26	00	2	1023.0	3	1.2	72.2	66.0	72.0	5	5	X	X	0	0	10	3	8
3/30	22.2°	146.3°	1200	98	10	22	00	2	1021.3	7	1.2	71.9	65.0	72.2	6	5	7	5	9	0	10	3	8
3/30	21.6°	145.7°	1800	98	08	24	15	2	1022.7	0	1.5	72.7	65.9	72.2	5	4	7	5	3	0	08	3	8
3/31	21.1°	145.6°	0000	98	10	20	02	2	1020.0	7	2.0	72.8	64.9	72.9	6	2	1	5	4	9	10	3	8
3/31	20.3°	145.5°	0600	98	10	21	02	2	1021.0	1	1.6	72.6	65.9	72.8	6	2	1	5	4	9	10	3	8
3/31	19.7°	145.9°	1200	98	10	19	02	2	1019.3	7	2.2	71.7	67.8	73.3	6	6	7	5	0	0	10	3	8
3/31	19.0°	146.6°	1800	98	09	19	15	2	1019.6	3	0.5	74.0	67.1	73.8	7	6	4	5	3	0	07	3	5

Table 8.--Summary of weather observations (USWB 1210-F), Hugh M. Smith cruise 51 (con.)

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. corr. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
4/1	18.4°	147.2°	0600	98	10	20	00	1	1018.0	2	1.0	73.1	69.0	74.0	2	2	1	5	0	0	09	3	4
4/1	17.6°	147.9°	1200	98	08	11	02	0	1016.6	7	1.4	74.0	69.5	74.7	1	1	1	5	0	0	09	3	4
4/1	16.7°	148.2°	1800	98	07	14	02	0	1018.0	2	1.0	75.6	70.7	74.4	2	2	1	5	0	0	08	3	4
4/2	15.9°	148.9°	0000	98	07	20	02	0	1014.9	7	2.5	75.8	71.3	75.5	3	3	1	5	0	0	08	3	4
4/2	15.0°	149.5°	0600	98	05	22	02	1	1015.2	2	0.7	76.7	71.2	75.9	2	2	1	5	0	0	07	3	4
4/2	15.7°	149.7°	1200	98	06	26	01	1	1014.2	8	2.0	75.0	69.6	75.2	2	2	1	5	0	0	07	3	7
4/2	16.4°	150.3°	1800	98	05	25	02	1	1016.6	2	1.5	75.2	66.5	75.1	2	2	1	5	4	1	05	3	8
4/3	16.4°	150.4°	0000	98	06	29	15	1	1013.2	8	2.0	75.0	70.0	75.5	5	5	4	5	0	0	06	3	8
4/3	17.1°	150.8°	0600	98	06	23	80	1	1015.6	0	2.0	75.5	70.0	75.4	2	2	4	5	0	0	06	3	8
4/3	17.9°	151.3°	1200	98	05	30	03	0	1015.6	8	1.0	73.5	69.0	75.2	3	3	8	5	0	0	56	3	1
4/3	18.6°	151.8°	1800	98	04	27	02	0	1018.3	2	2.0	72.4	67.0	74.0	1	1	1	5	1	0	04	3	9
4/4	19.4°	152.2°	0000	98	06	23	03	0	1016.6	8	2.2	74.5	66.4	74.7	4	1	1	5	9	0	05	3	8
4/4	20.4°	152.7°	0600	98	05	19	02	1	1019.0	1	2.1	72.7	64.4	73.9	2	2	1	5	0	0	04	3	7
4/4	21.1°	153.1°	1200	98	08	16	01	1	1018.3	7	1.8	71.6	67.0	74.0	2	2	1	5	0	0	05	3	7
4/4	21.8°	153.3°	1800	98	09	15	15	0	1015.9	3	0.7	73.4	67.0	73.9	2	2	1	5	3	0	07	3	6
4/5	22.5°	153.9°	0600	98	11	14	18	2	1018.6	3	2.0	72.4	67.0	74.0	6	6	1	5	X	X	04	3	5
4/5	23.3°	154.5°	1200	98	08	16	01	0	1017.6	7	1.4	70.5	66.4	72.0	2	2	1	5	0	0	05	3	5
4/5	24.2°	154.9°	1800	97	09	14	81	8	1018.3	2	1.4	69.6	66.7	71.4	7	7	7	5	0	0	05	3	5
4/6	23.8°	155.6°	0000	98	10	08	02	0	1015.6	7	2.5	72.8	67.7	73.0	3	3	1	5	0	0	08	4	3
4/6	22.6°	156.1°	0600	98	14	14	00	1	1014.6	3	0.3	74.2	68.4	74.1	1	1	2	5	0	0	15	3	3
4/6	22.2°	156.6°	1200	98	18	11	03	0	1013.9	8	1.2	74.3	69.3	74.0	2	2	1	5	0	0	15	3	3

Table 9.--Summary of weather observations (USWB 1210-F), Charles H. Gilbert cruise 44[1/]

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. corr. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
4/30	21.7°	158.2°	1800	99	45	08	00	X	1018.0	X	XX	77.0	70.2	75.3	2	1	1	4	3	0	15	2	1
5/1	22.5°	158.4°	0000	99	09	18	02	0	1016.6	7	1.4	78.2	71.4	76.0	3	1	2	5	3	1	08	2	3
5/1	22.5°	158.4°	0600	99	11	18	00	0	1017.6	2	1.7	74.1	69.6	74.1	9	9	X	0	X	X	08	2	3
5/1	23.3°	158.4°	1200	98	12	13	00	0	1017.3	7	1.5	74.0	69.9	74.2	2	9	X	X	X	X	08	2	3
5/1	24.1°	158.3°	1800	99	12	16	01	1	1018.3	1	1.6	75.1	69.5	73.4	7	6	8	5	0	1	08	2	2
5/2	24.1°	159.2°	0000	98	12	13	02	2	1017.3	7	1.5	75.3	69.8	75.0	5	2	2	5	3	1	09	2	3
5/2	23.8°	158.9°	0600	99	12	14	02	2	1016.6	3	0.6	74.5	70.0	74.9	5	4	4	5	0	1	09	2	3
5/2	23.2°	160.5°	1200	98	13	14	00	1	1016.3	7	1.2	75.0	69.6	75.0	2	2	1	5	0	0	09	2	3
5/3	22.5°	161.0°	0000	99	10	05	02	0	1o16.6	8	1.1	77.5	72.0	77.0	3	3	2	5	0	0	10	2	2
5/3	22.0°	161.2°	0600	99	07	10	02	0	1016.9	3	1.2	76.8	70.4	77.5	3	2	2	5	0	1	10	3	2
5/3	21.2°	161.9°	1200	98	08	08	00	0	1017.3	8	0.9	76.6	71.0	76.9	2	2	2	5	0	0	09	3	2
5/3	20.6°	162.2°	1800	99	07	11	02	0	1016.9	3	0.6	76.3	69.9	77.0	1	1	1	5	0	0	11	3	2
5/4	19.8°	116.8°	0000	99	07	11	02	0	1016.9	8	1.2	79.0	71.4	78.6	1	1	1	5	0	0	12	3	3
5/4	19.6°	162.1°	0600	99	07	10	03	1	1016.6	3	1.0	77.0	71.2	78.0	5	4	2	5	6	0	07	3	3
5/4	19.3°	161.3°	1200	98	11	09	03	2	1015.6	7	1.5	76.9	70.2	77.2	7	3	2	5	5	0	07	3	3
5/4	19.2°	160.8°	1800	98	09	08	15	2	1016.9	3	1.4	75.8	68.6	77.5	7	4	8	5	6	0	09	2	2
5/5	19.1°	160.9°	0000	99	08	16	01	2	1015.2	7	1.8	78.8	71.1	77.8	1	1	1	5	0	0	08	2	3
5/5	19.6°	160.2°	0600	99	08	12	03	0	1016.3	2	1.8	77.8	71.3	77.8	4	4	2	5	0	0	08	2	3
5/5	20.0°	159.5°	1200	98	10	14	00	2	1015.9	8	1.5	77.0	71.0	77.1	8	X	X	X	X	X	XX	X	3
5/5	20.5°	158.8	1800	98	08	14	01	2	1016.6	3	0.8	76.2	69.9	76.9	6	6	2	5	0	0	08	3	4

[1/] All columns in USWB 1210-F are not included here. Those deleted are:

Column 2 Day of week
" 3 Octant
" 13 Barometer as read
" 14 Barometer as corrected
" 17 Air temperature, °F.
" 23 Course of ship
" 24 Speed of ship
" 31 Diff. sea-air, °F.
" 32 Dew point, °F.

Table 9.--Summary of weather observations (USWB 1210-F), Charles H. Gilbert cruise 44 (con.)

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. corr. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
5/6	20.8°	158.1°	0000	98	07	18	03	0	1016.3	8	1.2	78.5	71.4	77.0	4	4	2	5	0	0	06	3	4
5/7	21.3°	157.7°	0000	98	06	19	00	1	1017.6	7	1.0	78.0	71.5	75.9	4	4	2	5	0	0	06	2	4
5/7	22.0°	157.1°	0600	98	08	25	01	1	1019.0	3	2.0	75.6	71.0	74.3	2	2	2	5	0	0	06	2	4
5/7	22.5°	156.6°	1200	98	08	22	02	0	1019.6	8	0.8	75.6	70.0	74.4	2	2	2	5	0	0	06	2	4
5/7	23.0°	156.1°	1800	97	07	23	50	2	1020.7	2	1.0	73.2	69.3	73.5	7	7	7	4	0	0	06	2	4
5/8	23.5°	155.5°	0000	98	06	22	02	1	1021.3	8	0.8	77.1	69.3	74.7	3	3	2	5	0	0	07	2	5
5/8	23.4°	154.7°	0600	98	05	22	02	0	1022.0	3	1.4	73.2	69.0	75.0	2	2	2	5	0	0	07	3	5
5/8	23.4°	154.1°	1200	98	06	21	02	0	1021.7	8	1.3	75.4	69.2	74.8	2	2	2	5	0	0	07	3	5
5/8	23.9°	153.5°	1800	98	07	22	15	0	1023.4	2	1.6	74.4	68.7	74.6	4	4	2	4	0	0	06	3	5
5/9	24.5°	152.9°	0000	98	06	18	02	1	1023.0	7	0.8	73.7	65.4	74.1	4	4	2	4	0	0	07	3	7
5/9	24.5°	152.0°	0600	98	05	24	00	X	1022.0	3	0.8	69.9	65.2	72.9	9	9	X	X	X	X	07	3	6
5/9	23.9°	151.5°	1200	98	04	22	00	X	1021.3	7	2.0	69.7	59.3	73.0	5	3	2	4	5	X	XX	X	6
5/9	23.0°	151.8°	1800	98	04	14	02	0	1021.0	2	0.8	71.4	63.5	74.0	2	1	2	5	4	0	07	3	4
5/10	22.3°	151.2°	0000	98	07	15	15	2	1019.0	7	1.8	71.4	65.7	73.6	7	7	4	5	0	0	06	3	5
5/10	21.6°	150.7°	0600	98	10	10	00	0	1018.6	3	0.6	72.0	65.6	74.1	9	9	X	X	X	X	06	2	4
5/10	21.0°	150.2°	1200	98	04	15	00	0	1016.6	7	2.0	72.7	67.8	74.6	1	1	2	5	0	0	06	2	4
5/10	20.3°	150.1°	1800	98	05	15	15	2	1016.9	1	1.0	73.4	67.6	74.5	7	3	4	5	6	8	05	2	3
5/11	19.7°	150.4°	0000	98	07	16	15	2	1015.6	7	1.5	74.8	67.9	75.8	7	2	4	5	6	1	07	2	3
5/11	19.1°	150.9°	0600	98	05	15	01	1	1014.9	2	0.7	73.7	66.6	75.8	1	1	2	5	0	0	06	2	3
5/11	18.4°	151.5°	1200	98	05	16	00	X	1013.5	7	1.8	74.7	68.9	75.7	7	2	2	5	6	X	XX	X	3
5/11	17.4°	151.5°	1800	98	05	14	15	2	1013.9	3	1.0	73.7	65.9	75.7	7	5	2	5	6	1	04	2	3
5/12	17.4°	151.5°	0000	99	04	16	02	2	1012.2	7	2.0	76.5	69.5	76.0	6	2	2	5	0	1	05	2	3
5/12	16.6°	151.8°	0600	98	03	19	01	2	1012.9	3	1.0	75.2	67.8	76.8	5	9	X	X	X	X	04	2	3
5/12	15.9°	152.3°	1200	98	05	19	00	2	1011.5	6	1.8	75.7	68.7	77.4	6	2	2	5	6	X	04	2	3
5/12	16.7°	152.7°	1800	98	04	17	01	2	1012.9	1	1.2	74.8	67.2	76.5	7	2	4	5	4	0	03	2	4
5/13	17.3°	153.0°	0000	99	05	17	01	0	1012.5	7	1.0	75.6	68.8	76.5	1	1	1	5	0	0	04	2	4
5/13	18.2°	153.3°	0600	99	06	16	03	1	1014.9	2	2.0	74.6	68.8	75.4	5	9	X	X	X	X	05	2	4
5/13	18.9°	153.6°	1200	98	10	12	00	5	1015.9	8	0.8	74.6	68.5	76.0	2	2	1	5	X	X	04	2	3
5/13	19.6°	153.8°	1800	98	08	13	15	8	1017.6	2	2.0	75.2	67.0	75.4	5	3	2	5	4	0	05	2	3
5/14	20.4°	154.0°	0000	98	06	16	03	2	1016.9	8	0.7	74.7	70.2	75.8	7	7	1	4	6	0	04	2	3
5/14	21.1°	154.2°	0600	98	07	15	02	2	1018.6	2	1.5	74.0	67.8	74.8	6	2	2	5	3	0	05	2	3
5/15	22.5°	154.5°	0000	98	08	15	02	1	1020.7	8	1.2	75.0	69.2	75.3	3	3	2	5	0	0	06	2	4
5/15	23.0°	154.3°	0600	98	09	16	15	1	1020.3	3	1.0	74.4	68.8	75.0	5	4	2	5	4	0	06	2	3
5/15	24.0°	154.4°	1800	98	07	20	25	6	1021.0	2	1.5	72.6	68.6	74.8	6	4	4	4	3	0	07	2	4
5/16	24.0°	115.2°	0000	98	08	18	02	0	1020.0	7	1.2	74.2	68.6	75.0	4	4	2	5	0	0	11	2	4

Table 9.--Summary of weather observations (USWB 1210-F), Charles H. Gilbert cruise 44 (con.)

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. corr. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
5/16	23.2°	154.6°	0600	98	09	20	02	0	1020.0	3	1.2	74.3	68.8	74.9	2	2	2	5	0	0	09	2	4
5/16	22.5°	155.0°	1200	98	08	20	02	0	1018.6	7	2.0	74.5	70.0	75.5	4	2	2	5	6	0	09	2	4
5/16	21.8°	155.4°	1800	97	11	21	81	8	1019.3	3	1.0	72.8	68.7	73.5	8	6	4	4	7	8	09	2	4
5/17	20.8°	155.8°	0000	98	09	17	15	0	1017.3	7	1.0	75.3	70.6	74.8	3	2	4	4	4	4	10	2	4
5/17	20.1°	156.2°	0600	98	04	21	03	1	1015.9	5	0.0	76.3	68.8	77.0	6	1	2	5	3	0	04	2	4
5/17	19.5°	156.6°	1200	98	32	03	02	2	1015.2	6	1.0	77.5	70.9	76.6	3	1	2	5	3	0	XX	X	3
5/17	18.5°	157.3°	1800	98	10	18	03	1	1016.6	3	1.4	77.8	71.2	76.5	7	1	2	5	3	8	10	3	4
5/18	17.8°	157.8°	0000	98	10	22	15	2	1015.2	6	2.0	77.7	73.0	77.3	7	2	7	5	3	8	09	3	4
5/18	18.4°	158.0°	0600	98	10	18	01	1	1016.3	2	1.4	76.6	72.3	76.9	3	1	2	5	3	9	07	3	4
5/18	19.2°	157.9°	1200	98	10	13	00	2	1015.9	7	1.2	76.8	71.9	76.8	7	2	2	5	3	X	07	3	3
5/18	20.0°	158.0°	1800	98	10	14	15	2	1017.6	2	1.4	76.0	72.4	76.8	5	2	4	5	6	0	08	2	3
5/19	21.0°	157.9°	0000	98	05	07	02	1	1017.3	7	1.0	77.8	72.4	77.8	3	3	2	5	0	0	05	2	3
5/21	21.0°	158.4°	0000	98	20	07	02	2	1014.9	8	1.0	77.0	72.0	77.9	7	1	2	5	6	0	18	3	2
5/21	20.5°	158.7°	0600	98	17	06	02	2	1014.9	2	1.0	76.4	71.8	77.3	6	3	2	5	0	2	17	3	2
5/21	19.6°	159.2°	1200	98	19	06	02	0	1014.2	7	1.5	76.1	71.0	77.8	3	1	2	5	6	0	16	3	2
5/21	19.1°	159.7°	1800	98	13	07	02	0	1014.9	2	1.2	76.8	71.0	78.2	2	1	2	5	0	1	13	3	2
5/22	18.6°	160.4°	0000	99	07	04	02	0	1015.2	8	1.0	79.1	71.2	80.6	2	2	2	5	0	0	14	3	2
5/22	18.0°	161.0°	0600	99	13	06	02	0	1014.2	3	0.8	77.5	71.8	78.9	1	1	2	5	6	0	14	3	2
5/22	18.8°	161.0°	1200	99	00	11	02	0	1014.6	8	1.7	74.9	71.8	78.0	2	1	2	5	6	0	33	3	2
5/22	19.5°	161.1°	1800	97	02	19	15	8	1014.9	3	1.0	74.0	70.0	77.2	8	8	5	4	X	X	35	3	3
5/23	20.3°	161.1°	0000	97	04	17	02	2	1014.6	8	0.8	75.8	67.8	77.8	6	2	5	4	6	0	02	3	4
5/23	21.1°	161.1°	0600	98	05	17	01	2	1014.9	2	1.0	74.2	65.8	77.4	6	6	5	4	0	0	36	3	5
5/23	21.8°	161.0°	1200	98	03	10	00	2	1015.6	8	1.0	73.0	64.5	75.4	6	2	5	4	6	0	02	3	5
5/24	23.1°	160.6°	0000	98	03	12	02	2	1015.6	6	1.0	73.5	64.7	75.4	6	4	5	4	6	0	36	3	3
5/24	23.1°	161.2°	0600	98	04	11	15	2	1015.6	2	1.0	72.0	64.6	76.2	8	8	4	5	0	0	02	4	5
5/24	23.8°	161.1°	1200	98	32	08	25	8	1015.6	7	0.9	69.0	64.5	74.8	2	2	2	5	0	0	02	4	5
5/24	24.8°	161.2°	1800	97	03	07	15	2	1016.6	2	1.0	68.0	63.5	74.1	7	5	4	5	7	0	01	2	3
5/25	24.3°	160.5°	0000	98	06	06	02	0	1016.9	8	0.4	72.0	64.7	76.1	2	2	2	5	0	0	01	3	5
5/25	23.8°	159.7°	0600	98	07	09	03	2	1016.9	3	1.0	72.3	63.8	76.0	8	8	4	5	X	X	02	3	3
5/25	23.3°	159.2°	1200	97	10	10	00	1	1016.3	8	1.5	73.1	66.5	75.2	7	1	2	5	6	0	02	3	3
5/25	22.5°	158.3°	1800	98	07	12	80	8	1016.9	3	0.8	73.0	67.4	74.4	7	7	4	5	0	0	09	2	3
5/26	21.8°	157.8°	0000	98	09	10	02	1	1015.9	7	1.0	76.0	71.6	76.0	3	2	2	5	6	0	10	2	3
5/27	22.0°	156.9°	0600	98	12	13	01	2	1015.9	2	1.4	75.2	71.6	75.1	5	2	4	5	3	1	11	2	3
5/27	22.4°	156.3°	1200	98	14	17	00	2	1016.3	7	1.2	74.9	70.8	75.1	2	1	4	5	3	X	12	2	3
5/27	23.2°	155.5°	1800	98	14	09	03	2	1018.0	2	1.2	75.8	70.0	76.2	8	3	2	5	0	4	12	2	3

Table 9.--Summary of weather observations (USWB 1210-F), Charles H. Gilbert cruise 44 (con.)

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. corr. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
5/28	23.8°	154.6°	0000	98	13	12	02	2	1017.3	7	0.8	75.9	70.0	76.6	6	4	2	5	2	4	11	2	3
5/28	24.4°	153.7°	0600	98	12	11	03	2	1018.6	3	1.5	74.8	68.5	75.0	5	2	4	5	X	X	11	2	3
5/28	24.8°	153.0°	1200	98	12	10	00	2	1018.3	7	1.0	73.5	68.9	74.9	2	2	4	5	X	X	11	2	3
5/28	23.0°	153.0°	1800	98	11	10	03	1	1019.0	1	1.0	74.5	69.2	76.0	7	1	2	5	7	7	13	2	3
5/29	23.2°	152.8°	0000	98	12	12	15	2	1018.3	7	1.0	75.6	70.0	76.0	7	1	2	5	7	7	13	2	3
5/29	22.0°	152.7°	0600	98	14	09	01	1	1018.6	3	1.0	75.0	69.0	75.2	1	9	X	0	X	X	11	2	3
5/29	21.3°	152.8°	1200	98	08	17	00	2	1017.3	7	2.0	75.1	70.7	75.7	7	1	2	5	X	X	09	2	3
5/29	20.4°	152.7°	1800	98	08	20	15	8	1017.6	3	1.0	75.2	72.1	77.0	6	5	4	4	0	1	10	2	4
5/30	19.3°	153.0°	0000	98	07	19	15	8	1016.3	7	1.2	77.2	73.1	77.4	3	3	2	4	0	0	11	2	4
5/30	18.4°	152.1°	0600	98	09	18	00	8	1016.9	2	1.0	76.6	72.8	77.0	9	9	X	0	X	X	09	2	4
5/30	17.5°	153.0°	1200	98	07	19	00	1	1015.6	6	1.5	76.2	71.5	77.2	1	1	2	4	0	0	10	2	4
5/30	17.3°	153.8°	1800	98	07	16	01	0	1016.6	2	1.6	76.6	70.2	77.5	2	1	2	4	0	1	09	2	4
5/31	17.6°	154.3°	0000	98	05	15	02	0	1015.2	7	1.3	77.1	70.3	77.6	2	2	2	4	0	0	08	2	5
5/31	17.8°	155.2°	0600	97	06	17	02	0	1015.9	2	1.0	76.3	70.5	77.3	2	2	2	4	0	0	05	2	4
6/1	20.4°	156.6°	0600	98	07	18	03	0	1015.9	2	2.0	75.4	70.0	76.5	2	1	2	[illegible]	0	2	06	2	4
6/1	20.9°	157.5°	1200	98	08	19	00	0	1015.9	7	0.4	75.2	70.0	77.1	1	1	X	X	0	0	XX	X	3

Table 10.--Summary of weather observations (USWB 1210-F), Charles H. Gilbert cruise 45[1/]

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. corr. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
7/10	21.1°	157.8°	0000	99	11	10	01	0	1016.3	8	1.0	77.5	71.8	78.6	1	1	8	6	1	0	04	3	2
7/10	21.1°	157.8°	0600	98	06	17	02	0	1016.3	2	1.0	76.8	72.4	78.6	2	1	1	6	1	0	06	3	2
7/10	21.2°	157.7°	1800	99	09	10	03	2	1018.0	2	1.9	77.9	73.4	78.0	7	6	8	6	1	0	08	3	2
7/13	21.5°	158.2°	1800	99	30	01	00	0	1018.3	3	1.0	78.4	71.0	78.9	1	0	0	9	6	0	16	3	0
7/14	21.2°	158.2°	0000	99	03	02	03	0	1017.3	8	1.4	81.7	73.1	79.9	1	1	2	6	0	1	08	3	0
7/14	21.3°	157.9°	1800	99	05	15	00	2	1017.3	2	1.5	79.1	73.0	78.2	6	5	8	6	2	0	12	3	2
7/18	20.5°	158.3°	0000	99	06	18	03	1	1015.2	7	1.4	79.2	75.2	79.4	5	5	4	6	0	0	08	3	3
7/18	20.3°	158.9°	0600	XX	04	09	01	1	1015.6	2	1.4	80.1	74.9	79.2	4	4	4	6	0	0	07	3	2
7/18	19.6°	159.5°	1200	96	08	11	02	1	1015.2	7	1.4	78.5	75.6	78.5	4	4	4	6	0	0	07	3	2
7/18	19.0°	160.0°	1800	98	09	17	01	0	1018.3	3	1.6	79.8	75.3	78.6	3	1	2	6	0	4	10	3	3
7/19	18.4°	160.6°	0000	98	11	13	02	2	1013.9	7	1.9	80.0	75.3	79.1	6	6	2	6	0	0	11	3	2
7/19	18.2°	162.3°	0600	98	08	13	01	1	1013.9	2	1.2	80.0	75.3	79.8	1	1	4	6	0	0	08	3	2
7/19	18.7°	161.8°	1200	94	08	17	02	2	1014.2	8	1.0	78.9	74.5	79.5	5	5	1	6	0	0	08	3	3
7/19	19.2°	162.3°	1800	98	09	19	01	1	1014.6	3	0.7	80.0	74.5	79.4	1	1	4	6	0	0	05	3	3
7/20	19.8°	163.1°	0000	98	09	15	02	1	1015.2	7	1.0	80.0	74.3	80.0	4	4	4	6	0	0	08	3	3
7/20	20.6°	163.6°	0600	98	07	18	15	0	1015.2	2	1.4	79.9	75.2	79.9	4	4	1	6	0	0	07	3	3
7/20	21.2°	164.1°	1200	94	10	16	02	1	1016.3	7	1.0	78.8	74.6	79.0	4	4	2	6	0	0	09	3	3
7/20	21.9°	164.8°	1800	98	09	13	03	0	1016.6	3	0.9	79.3	74.2	78.5	3	3	2	5	0	0	09	3	2
7/21	22.5°	165.4°	0000	98	09	13	02	1	1016.9	7	0.9	80.0	74.3	79.6	4	4	2	5	0	0	09	3	2
7/21	23.3°	166.1°	0600	98	08	14	01	0	1016.6	2	1.0	78.9	72.7	79.6	1	1	1	6	0	0	09	3	2

[1/] All columns in USWB 1210-F are not included here. Those deleted are:

Column	2	Day of week
"	3	Octant
"	13	Barometer as read
"	14	Barometer as corrected
"	17	Air temperature, °F.
"	23	Course of ship
"	24	Speed of ship
"	31	Diff. sea-air, °F.
"	32	Dew point, °F.

Table 10.--Summary of weather observations (USWB 1210-F), Charles H. Gilbert cruise 45 (con.)

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. corr. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
7/23	24.2°	165.7°	0000	98	10	09	03	2	1016.9	7	1.0	78.9	73.6	79.1	7	1	2	5	1	6	10	3	3
7/23	24.5°	165.1°	0600	98	10	09	02	2	1016.9	2	1.0	78.4	75.0	78.8	7	2	2	5	1	5	09	3	3
7/23	24.8°	164.0°	1200	98	07	09	01	0	1016.6	6	1.4	75.6	72.3	79.0	1	1	1	5	0	0	09	3	3
7/23	25.1°	163.2°	1800	98	08	08	03	1	1017.6	2	1.0	77.0	72.0	78.5	4	4	2	5	0	0	09	3	2
7/24	25.4°	162.1°	0000	98	07	00	01	0	1017.3	7	0.5	80.6	72.3	81.5	3	3	1	6	0	0	09	3	3
7/24	24.6°	161.2°	0600	98	07	02	03	1	1017.3	2	0.7	77.5	72.0	80.0	6	6	2	5	0	0	09	3	3
7/24	25.8°	160.8°	1200	98	09	07	01	1	1017.3	6	0.9	76.6	73.0	78.6	2	2	1	5	0	0	09	3	5
7/24	24.8°	160.3°	1800	98	09	03	02	0	1018.0	X	XX	75.1	72.0	78.7	3	3	6	5	0	0	09	3	3
7/25	24.0°	159.6°	0000	98	10	05	01	0	1018.0	4	0.0	79.7	71.4	81.2	1	1	2	6	0	0	11	3	3
7/25	23.2°	159.0°	0600	98	11	07	03	1	1017.3	4	0.0	80.2	75.0	80.0	4	4	2	5	0	0	11	3	3
7/25	22.5°	163.5°	1200	98	10	10	25	0	1016.9	7	1.4	78.8	74.7	79.0	4	4	1	5	0	0	10	3	3
7/25	22.2°	157.6°	1800	98	00	00	01	0	1017.3	2	0.9	80.1	75.1	78.1	4	4	2	5	0	0	09	3	2
7/26	22.5°	157.1°	0000	98	10	07	25	1	1016.6	6	1.0	80.0	75.0	80.3	7	1	2	6	0	6	04	3	3
7/26	22.8°	156.3°	0600	98	10	02	20	2	1016.9	2	0.9	79.1	75.0	79.1	7	7	2	5	0	5	06	3	2
7/26	23.3°	155.5°	1200	97	07	17	20	2	1016.9	7	1.0	79.1	75.0	78.8	7	7	2	4	X	X	05	3	4
7/26	23.9°	154.8°	1800	98	09	18	01	0	1018.3	2	1.0	77.3	72.8	77.1	3	2	4	6	2	0	08	3	3
7/27	24.6°	154.2°	0000	98	06	09	02	0	1018.3	4	0.0	79.2	72.5	78.0	4	4	2	6	0	0	08	3	3
7/27	25.4°	153.5°	0600	95	08	15	02	2	1019.0	2	1.0	77.1	70.8	77.3	6	6	4	6	0	0	08	3	3
7/27	25.9°	153.0°	1200	97	10	16	01	2	1019.0	7	0.8	77.4	70.5	77.2	5	5	2	6	0	0	08	3	3
7/27	24.9°	152.9°	1800	98	09	15	00	2	1019.6	2	1.0	76.3	71.0	77.1	6	5	8	6	0	1	08	3	3
7/28	23.9°	152.9°	0000	98	10	12	02	2	1018.6	7	1.0	78.0	72.1	77.5	5	4	8	6	0	1	10	3	3
7/28	23.0°	152.9°	0600	98	07	13	01	1	1018.3	3	0.8	77.2	72.2	77.6	3	3	8	6	0	0	10	3	2
7/28	22.1°	152.9°	1200	97	08	18	03	1	1016.9	7	1.5	77.3	73.1	78.0	6	6	8	5	0	0	10	3	3
7/28	21.1°	152.9°	1800	98	08	10	50	2	1016.9	2	0.5	75.2	74.0	77.7	6	6	8	5	0	0	10	3	2
7/29	20.2°	152.9°	0000	98	08	14	15	1	1015.6	7	1.0	79.5	74.5	78.4	4	4	8	5	0	0	09	3	2
7/29	19.1°	152.9°	0600	95	08	14	02	0	1015.2	3	1.0	77.9	74.3	77.9	3	3	8	5	0	0	09	3	2
7/29	18.4°	152.9°	1200	98	08	14	02	0	1013.5	7	2.0	78.0	75.0	78.0	4	4	8	5	0	0	08	3	2
7/29	17.3°	153.0°	1800	98	08	13	15	2	1013.9	2	1.0	78.0	74.8	78.1	6	6	4	5	0	0	10	3	2
7/30	17.0°	153.7°	0000	98	09	10	02	1	1013.2	7	1.5	83.0	75.3	78.8	4	4	8	6	0	0	09	3	2
7/30	16.8°	154.7°	0600	95	07	15	00	0	1013.2	3	1.0	79.5	74.5	78.6	3	3	8	6	0	0	09	3	2
7/30	17.0°	155.6°	1200	95	05	13	02	0	1012.9	7	1.0	78.9	74.9	78.4	2	2	8	6	0	0	09	3	2
7/30	17.4°	156.2°	1800	98	08	14	03	1	1013.9	2	1.3	79.4	75.0	78.5	5	5	1	5	0	0	08	3	2
7/31	18.4°	156.7°	0000	98	09	13	03	2	1013.2	8	1.0	78.9	74.2	79.4	6	1	4	5	0	4	09	3	2
7/31	19.3°	157.2°	0600	97	02	08	15	1	1013.9	2	1.2	81.5	75.4	80.8	3	3	2	6	0	0	06	2	2
7/31	20.2°	157.5°	1200	95	07	14	01	0	1013.5	X	XX	80.3	75.6	80.2	2	2	2	X	0	0	08	2	2

Table 10.--Summary of weather observations (USWB 1210-F), Charles H. Gilbert cruise 45 (con.)

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. corr. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
8/3	21.3°	158.3°	0000	98	08	11	00	1	1014.6	8	1.6	84.1	74.3	81.0	4	4	1	6	0	0	12	2	2
8/4	21.2°	158.4°	0000	99	07	13	03	1	1013.9	8	1.5	80.7	75.7	80.5	7	7	1	6	0	0	07	2	3
8/4	21.3°	158.2°	0600	98	09	10	01	0	1013.5	2	1.0	79.5	72.5	80.0	1	1	8	6	0	0	XX	X	X
8/4	21.1°	158.2°	1800	98	09	09	03	2	1014.2	3	0.9	80.7	71.1	80.0	7	7	2	5	0	0	XX	X	X
8/5	21.2°	158.1°	0000	99	07	25	02	0	1012.5	7	1.5	81.3	72.9	79.9	5	5	1	6	0	0	13	2	2
8/10	20.9°	158.3°	0000	99	09	15	01	0	1015.2	8	1.7	79.4	75.8	78.8	1	1	1	6	1	0	07	2	3
8/10	21.3°	158.2°	0600	97	08	12	00	1	1015.9	2	2.0	79.5	74.0	78.6	4	4	4	4	0	0	XX	0	0
8/10	21.4°	158.2°	1800	98	02	06	00	X	1016.9	2	1.0	80.0	70.4	78.8	1	1	4	4	0	0	15	0	0
8/11	21.2°	158.1°	0000	99	09	14	03	0	1015.2	6	1.6	80.8	74.6	79.0	1	1	4	4	0	0	10	2	2
8/14	21.5°	157.7°	1800	98	08	12	00	X	1016.6	2	1.0	79.3	73.0	73.4	4	4	4	4	0	0	09	2	2
8/15	21.0°	157.2°	0000	99	02	19	01	0	1014.9	7	1.5	81.3	73.6	79.4	2	1	1	4	4	0	04	2	2
8/17	21.5°	158.3°	0600	98	01	09	00	X	1012.5	2	1.0	79.0	71.5	79.2	5	5	4	4	0	0	XX	X	X
8/17	21.4°	158.8°	1800	98	10	07	00	X	1013.2	2	1.0	80.3	70.5	79.1	4	4	4	4	0	0	18	2	1
8/18	21.1°	157.8°	0000	98	06	15	02	0	1011.9	6	1.4	78.1	73.6	79.1	1	1	1	4	0	0	06	2	3
8/19	21.1°	157.9°	0000	98	03	15	01	0	1013.5	7	0.6	79.0	74.9	79.4	1	1	1	4	1	0	04	2	3
8/20			0000	98	09	14	02	0	1015.6	7	1.4	81.1	76.0	80.0	1	1	1	4	0	0	08	2	2
8/24	21.5°	158.4°	0000	98	23	10	03	0	1013.2	6	1.1	81.8	74.0	80.1	1	1	1	4	0	0	02	2	2
8/26	21.1°	156.8°	0000	98	07	20	03	0	1012.9	8	1.5	80.1	74.8	78.2	2	2	1	4	1	0	07	2	3
8/26	20.9°	156.5°	0600	97	30	16	00	X	1014.6	2	2.0	77.3	72.2	79.1	9	X	X	X	X	X	XX	X	0
8/27	21.0°	156.6°	1800	97	07	18	00	X	1015.2	4	0.0	77.9	72.4	78.4	5	4	4	4	0	1	08	2	3
8/28	20.8°	157.0°	0600	98	00	16	01	1	1013.2	2	1.5	78.0	70.0	79.0	1	1	4	4	0	0	XX	1	0
8/28	20.7°	157.0°	1800	98	14	06	00	X	1013.9	1	1.0	79.3	69.0	79.8	3	3	4	4	0	0	03	1	1
8/29	21.0°	157.9°	0000	99	11	27	01	0	1013.9	0	0.6	79.7	73.6	79.7	1	1	1	4	2	0	08	2	3
8/30	21.1°	158.1°	0000	98	10	20	03	0	1013.9	6	1.5	84.2	73.8	79.5	2	2	1	4	0	0	10	2	2
8/31	21.4°	158.4°	0000	98	05	19	01	0	1013.2	7	1.2	81.2	74.0	74.3	1	1	1	4	0	0	05	2	3
8/31	21.4°	158.2°	0600	98	03	11	00	0	1012.9	2	1.0	78.1	69.0	79.1	1	1	4	4	0	0	XX	0	0
8/31	21.5°	158.3°	1800	98	34	10	00	0	1013.5	2	0.8	79.3	70.5	79.0	1	1	4	4	0	0	34	1	1
9/1	21.3°	158.1°	0000	98	02	21	01	0	1011.5	7	1.5	80.1	73.5	79.4	1	1	1	4	0	0	12	2	4

Table 11.--Summary of weather observations (USWB 1210-F), Charles H. Gilbert cruise 46[1]

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. corr. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
9/17	21.4°	158.3°	0000	98	12	10	01	2	1014.2	7	2.0	82.3	73.3	80.2	3	3	1	6	1	0	15	3	2
9/18	21.2°	158.0°	1800	97	08	16	00	X	1014.9	2	1.0	80.4	74.6	79.7	3	3	2	4	0	0	13	2	2
9/19	21.4°	158.2°	0000	98	05	14	03	1	1014.2	8	0.9	81.0	72.8	80.3	7	7	4	5	0	0	04	2	2
9/19	21.2°	157.8°	1800	97	10	14	00	X	1017.3	2	1.0	79.1	73.0	78.4	7	3	2	4	1	0	13	2	2
9/20	21.5°	157.8°	0600	97	01	14	00	2	1017.6	2	1.2	79.0	71.5	79.1	X	X	X	X	X	X	01	2	0
9/20	21.5°	157.8°	1800	97	04	16	02	2	1017.6	2	1.0	79.2	72.2	78.5	6	6	1	4	0	0	04	2	0
9/21	21.5°	157.7°	0000	98	08	14	01	0	1014.6	X	XX	79.0	72.0	79.3	4	4	1	4	0	0	09	3	4
9/21	21.2°	158.3°	0600	97	30	08	00	1	1015.2	2	0.4	78.5	70.0	80.4	2	2	1	4	0	0	XX	2	0
9/21	21.7°	158.1°	1800	97	08	15	00	X	1015.2	2	1.0	77.0	72.8	78.9	6	6	1	4	0	0	04	2	3
9/22	21.3°	158.2°	0000	98	08	15	03	0	1013.2	7	2.0	82.7	72.2	80.4	3	3	1	4	0	0	08	2	3
9/22	21.4°	157.8°	1800	97	08	22	00	0	1014.6	2	1.0	80.8	74.2	79.2	3	1	2	4	4	0	13	2	3
9/23	20.8°	157.2°	0000	98	08	21	00	0	1012.9	8	2.1	79.8	74.1	80.1	1	1	2	4	1	1	10	2	4
9/23	20.7°	157.0°	0600	98	33	06	01	1	1014.6	2	1.2	80.0	71.0	81.0	X	X	X	X	X	X	33	2	0
9/23	20.7°	157.0°	1800	98	03	09	00	X	1014.6	2	1.0	80.1	71.6	79.8	2	2	1	4	0	0	03	2	0
9/24	20.9°	157.5°	0000	98	27	02	03	X	1013.2	8	1.5	81.1	72.8	80.9	6	6	4	4	0	0	02	2	2
9/25	21.2°	157.8°	1800	97	08	20	00	X	1015.9	2	1.0	80.0	73.0	79.6	7	7	1	4	0	0	13	2	2
9/26	21.2°	158.0°	1800	98	36	05	00	X	1015.9	2	1.0	78.6	73.0	79.8	3	3	4	4	0	0	20	2	1
9/27	21.5°	158.3°	0000	98	04	04	03	1	1014.6	8	1.7	83.4	73.8	82.2	6	5	4	4	2	0	16	2	1
9/30			0000	98	09	15	02	2	1013.5	7	2.1	80.7	75.6	80.6	6	4	2	4	6	2	19	2	3
9/30	19.8°	157.2°	0600	96	09	10	20	2	1015.6	2	2.0	77.9	75.0	80.2	7	X	X	X	X	X	09	2	2

---

[1] All columns in USWB 1210-F are not included here. Those deleted are:

Column	2	Day of week
"	3	Octant
"	13	Barometer as read
"	14	Barometer as corrected
"	17	Air temperature, °F.
"	23	Course of ship
"	24	Speed of ship
"	31	Diff. sea-air, °F.
"	32	Dew point, °F.

Table 11.--Summary of weather observations (USWB 1210-F), Charles H. Gilbert cruise 46 (con.)

Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
					Direction	Speed (kn.)	Present	Past	Bar. corr. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
9/30	19.2°	157.3°	1800	96	08	09	20	6	1015.2	2	1.4	77.5	75.0	80.5	9	X	X	X	X	X	18	2	2
10/1	19.5°	157.1°	0000	98	18	07	01	2	1012.0	7	2.2	80.9	74.4	81.2	7	5	2	4	6	0	12	3	3
10/1	18.7°	156.5°	0600	96	09	16	02	2	1013.5	2	1.7	80.7	74.0	79.1	8	X	X	X	X	X	13	3	4
10/1	18.1°	155.9°	1200	96	07	14	01	0	1012.5	7	1.3	79.5	74.3	79.7	3	X	X	X	X	X	06	3	3
10/1	17.2°	155.1°	1800	97	06	13	02	0	1014.2	2	2.0	80.8	74.5	80.0	3	2	8	4	6	0	08	3	3
10/2	17.5°	154.6°	0000	98	04	12	02	0	1012.5	7	1.9	79.7	74.1	80.0	4	3	2	4	6	0	06	2	3
10/2	17.2°	154.0°	0600	96	06	10	01	0	1013.2	2	1.5	79.8	74.4	79.9	2	X	X	X	X	X	06	3	2
10/2	17.1°	153.5°	1200	96	07	07	03	2	1012.2	7	1.7	79.2	73.0	80.3	7	X	X	X	X	X	06	3	2
10/2	17.0°	153.1°	1800	98	08	12	01	0	1013.5	2	1.8	79.9	74.8	81.0	2	2	8	0	0	0	09	3	2
10/3	17.9°	153.2°	0600	96	09	10	02	0	1013.2	2	1.5	78.1	72.9	79.7	2	X	X	X	X	X	08	3	2
10/3	18.5°	153.2°	1200	96	05	05	20	2	1013.5	4	0.0	76.7	73.3	78.9	7	X	X	X	X	X	00	X	1
10/3	19.2°	153.2°	1800	97	08	09	18	2	1014.2	2	1.5	77.7	72.0	78.1	6	4	5	3	6	0	04	2	1
10/4	20.4°	153.1°	0000	99	08	06	01	0	1013.2	6	2.0	78.5	72.6	78.9	1	1	2	4	0	0	03	2	1
10/4	21.3°	153.0°	0600	99	08	06	02	0	1014.9	2	2.0	77.0	69.8	79.0	3	X	X	X	X	X	03	2	1
10/4	22.1°	153.0°	1200	97	08	11	02	0	1014.6	7	1.0	76.4	72.0	78.0	3	X	X	X	X	X	03	2	1
10/4	22.9°	153.0°	1800	97	00	02	02	0	1015.2	2	1.5	76.0	71.7	77.7	2	2	2	5	0	0	03	2	1
10/5	22.8°	153.6°	0600	97	13	12	03	2	1015.6	2	2.0	78.1	73.9	78.5	7	X	X	X	X	X	09	3	2
10/5	22.3°	154.2°	1200	96	13	13	02	2	1015.2	7	1.0	78.3	73.8	78.4	4	X	X	X	X	X	10	3	3
10/5	21.6°	155.1°	1800	98	11	11	03	1	1015.6	2	1.2	79.8	74.8	78.4	5	5	8	5	0	0	13	3	2
10/6	21.2°	155.7°	0000	99	12	09	01	1	1014.2	7	2.0	79.6	75.8	79.7	2	2	2	5	6	0	13	3	1
10/9	20.4°	157.9°	0600	97	13	10	02	2	1014.2	2	2.0	81.1	74.1	80.8	6	X	X	X	X	X	13	3	3
10/9	19.6°	158.2°	1200	97	16	12	03	2	1015.2	8	0.5	76.5	70.8	80.0	8	X	X	X	X	X	09	4	3
10/9	19.0°	158.9°	1800	98	09	12	03	1	1015.2	2	1.0	80.0	74.1	80.0	5	5	8	5	0	0	09	3	2
10/10	18.5°	159.4°	0000	98	11	10	02	0	1013.9	7	1.9	81.1	73.7	80.8	2	2	8	4	0	0	12	3	3
10/10	18.0°	160.1°	0600	97	08	15	02	2	1015.6	2	2.0	80.0	74.2	80.0	6	6	8	4	0	0	09	3	3
10/10	17.0°	160.1°	1200	96	12	17	02	2	1014.9	7	1.0	80.3	74.7	80.0	8	8	8	4	0	0	09	3	4
10/10	16.4°	160.1°	1800	97	09	14	02	2	1014.9	2	1.0	80.8	75.8	80.5	6	6	8	4	0	0	08	3	4
10/11	15.5°	160.2°	0600	96	08	16	20	2	1013.9	2	1.8	81.0	76.7	80.9	8	8	8	4	0	0	06	3	3
10/11	15.6°	160.6°	1200	96	07	12	02	2	1013.9	8	1.0	80.2	77.1	80.8	5	3	8	4	6	0	06	3	3
10/11	16.1°	161.3°	1800	98	05	14	02	2	1014.9	2	2.0	79.5	76.0	80.0	4	4	8	5	0	0	07	3	3
10/12	16.6°	162.3°	0000	98	07	17	02	0	1012.9	7	2.5	80.4	75.4	81.0	4	4	8	5	6	0	07	3	3
10/12	17.1°	163.0°	0600	98	08	12	02	0	1013.9	2	1.7	80.0	74.9	80.6	3	3	2	5	6	0	07	3	3
10/12	17.5°	163.4°	1200	97	05	10	01	0	1014.6	7	1.0	79.4	73.9	80.6	3	3	2	5	0	0	07	3	3
10/12	18.5°	163.9°	1800	98	09	14	03	0	1015.2	2	1.0	80.0	73.7	81.2	4	4	2	4	6	0	07	4	3
10/13	18.7°	164.3°	0000	98	08	09	02	0	1014.6	7	2.0	81.8	74.0	80.6	4	4	8	5	6	0	08	4	3

Table 11.--Summary of weather observations (USWB 1210-F), Charles H. Gilbert cruise 46 (con.)

					Wind		Weather		Pressure			Temperature (° F.)			Clouds						Waves		
Date, 1959	Latitude N.	Longitude W.	Time (GCT)	Visibility	Direction	Speed (kn.)	Present	Past	Bar. corr. (mb.)	Characteristic	Amt. change	Dry bulb	Wet bulb	Sea water	Total amount	Amount low	Type low	Height low	Type middle	Type high	Direction	Period	Height
10/13	18.1°	165.0°	0600	98	06	13	02	0	1014.6	2	1.0	80.9	74.8	81.7	3	2	2	4	6	0	09	4	3
10/13	17.6°	165.4°	1200	98	08	14	02	0	1013.9	7	1.2	80.5	75.2	81.7	4	4	2	4	0	0	08	4	3
10/13	16.9°	166.1°	1800	97	10	12	18	1	1013.9	2	1.5	80.0	74.8	80.8	6	6	8	5	0	0	08	3	4
10/14	16.9°	166.6°	0000	97	09	11	02	1	1012.9	7	2.0	81.0	74.9	81.6	4	3	2	5	6	0	09	3	4
10/14	17.7°	167.2°	0600	96	10	15	03	2	1013.5	2	2.2	80.1	76.1	81.4	7	7	8	4	0	0	06	3	4
10/14	18.7°	167.3°	1200	97	04	10	02	0	1014.2	8	0.5	80.1	74.3	81.6	3	3	2	4	0	0	04	3	4
10/14	19.6°	167.5°	1800	98	04	17	03	1	1014.2	2	1.0	80.0	75.1	81.1	4	4	8	5	6	0	04	3	4
10/15	20.4°	167.0°	0000	98	06	13	02	0	1013.5	7	1.0	81.4	75.0	81.5	2	2	2	5	0	0	06	3	4
10/15	20.7°	166.3°	0600	98	07	13	03	1	1013.5	2	1.0	78.7	73.4	81.8	5	5	8	5	0	0	06	3	4
10/15	20.5°	165.6°	1200	97	07	14	03	2	1014.2	7	0.7	80.3	74.5	81.5	6	6	8	4	0	0	07	3	4
10/15	20.4°	164.5°	1800	98	06	12	01	1	1014.2	2	1.0	81.5	74.0	81.3	3	3	2	4	6	0	07	2	4
10/16	20.7°	164.0°	0000	98	04	12	03	1	1013.2	7	1.8	81.6	75.0	81.6	7	6	2	4	6	0	05	2	3
10/16	21.2°	163.1°	0600	97	09	12	02	2	1014.2	2	1.7	80.5	75.2	81.4	6	5	2	4	6	0	06	2	3
10/16	21.7°	162.8°	1200	97	07	14	01	0	1015.2	8	0.2	80.3	74.0	81.3	2	2	2	4	0	0	06	2	3
10/16	22.7°	162.2°	1800	98	08	12	02	0	1015.9	2	1.0	80.0	74.8	79.7	2	2	2	4	0	0	06	2	4
10/17	23.0°	161.9°	0000	98	11	14	02	0	1015.2	7	2.0	80.2	73.8	80.0	2	2	1	4	6	0	12	2	4
10/17	22.1°	161.6°	0600	97	07	14	02	0	1015.6	7	1.0	79.8	73.3	80.7	3	3	2	4	0	0	10	3	4
10/17	21.3°	161.3°	1200	97	09	16	01	1	1015.2	7	1.0	79.7	71.8	80.6	3	3	2	4	0	0	10	3	4
10/17	21.7°	160.4°	1800	98	08	18	02	0	1015.9	2	1.5	79.5	72.8	80.8	3	3	2	4	0	0	10	3	4
10/18	22.9°	157.5°	0600	97	10	14	03	1	1017.6	2	2.0	80.2	74.2	80.4	4	4	2	4	0	0	08	3	4
10/18	22.5°	159.3°	1200	97	08	12	02	0	1018.0	8	1.0	78.3	72.1	80.0	3	3	2	4	0	0	11	3	4
10/18	21.6°	158.5°	1800	97	08	16	03	0	1018.3	2	1.5	78.3	70.6	79.5	4	4	2	4	0	0	11	3	4

Table 12.--Light penetration and water color 1/

Cruise	Date, 1959	Latitude N.	Longitude W.	Sea 2/	Cloud cover 2/	Water color (Forel)	Secchi disc (meters)
Hugh M. Smith 50	1/14	15°08'	149°37'	6	2	3	28
	1/16	16°39'	147°11'	7	3	3	26
	1/20	21°02'	148°00'	2	2	3	31
	1/22	24°32'	149°15'	5	1	2	33
Hugh M. Smith 51	3/13	18°23'	147°25'	3	2	-	31
	3/14	15°26'	148°35'	1	1	1	46
	3/15	14°49'	150°12'	2	2	2	40
	3/23	20°28'	161°03'	2	6	1	38
Charles H. Gilbert 45	6/19	19°39'	162°52'	3	3	2	33
	6/20	22°19'	165°12'	2	5	1	29
	6/22	24°03'	165°05'	2	5	1	36
	6/23	25°17'	162°24'	1	1	1	36
	6/27	24°13'	152°55'	2	5	1	36
	6/28	20°29'	152°51'	2	4	2	39
	6/29	16°57'	153°25'	3	4	1	41
Charles H. Gilbert 46	10/1	17°34'	154°58'	3	3	2	31
	10/2	17°00'	153°15'	1	3	2	33
	10/3	20°06'	153°07'	1	3	1	38
	10/4	22°50'	153°00'	2	3	1	35
	10/5	21°20'	155°33'	2	4(?)	2	29
	10/9	18°41'	159°14'	2	4	3	31
	10/10	16°24'	160°51'	3	7	2	37
	10/12	19°01'	164°04'	2	4	1	27

1/ All observations at local apparent noon.

2/ Sea state and cloud cover coded according to H.O. Pub. 606-c, second edition, 1956.

Table 13.--Zooplankton station positions and sample weights, *Hugh M. Smith* cruise 50

Station 1/	Sample	Date, 1959 2/	Position		Water strained $m.^3$	Weight (g./1,000 $m.^3$) 3/
			Lat. N.	Long. W.		
1	1	1/10	17°28'	154°40.2'	1,338.4	26.2
2	1	1/11	14°41.5'	152°21'	1,154.4	9.5
3A	1	1/12	12°41.5'	150°23.5'	1,056.8	23.7
3B	1	1/12	12°42'	150°22'	1,291.8	33.3
5	1	1/13	13°30'	149°34.8'	1,361.2	37.5
7	1	1/14	15°43'	149°16.2'	1,459.3	41.8
9	1	1/15	17°14.5'	148°36.5'	1,654.1	27.2
11A	1	1/16	17°19.5'	147°16.3'	1,475.6	22.4
11B	1	1/16	17°19.5'	147°14'	1,358.0	15.5
12	1	1/17	20°20.5'	148°58'	1,403.5	12.1
13	1	1/19	21°48'	148°48.8'	1,544.7	18.1
15	1	1/20	21°19'	148°01.3'	1,431.7	19.6
17	1	1/21	23°13'	148°22.8'	1,315.8	19.0
19	1	1/22	23°14'	149°31'	1,495.7	21.4
20	1	1/23	19°55'	151°32.8'	1,372.5	14.6
21	1	1/24	19°55'	153°46.2'	1,373.2	9.5
22	1	1/25	22°52'	154°30'	1,467.4	36.1
24A	1	1/26	21°58.3'	153°13'	1,357.8	33.1
24B	1	1/26	21°57.8'	153°10'	1,610.9	27.9
25	1	1/28	18°02.5'	156°35.5'	1,634.2	22.6
26	1	1/29	18°11'	159°30.6'	1,400.1	18.6
27	1	1/30	20°32.2'	162°19.8'	1,407.8	32.0
28	1	2/1	19°44'	165°20'	1,246.4	12.8
30	1	2/2	18°05.2'	166°02'	1,471.5	27.9
31	1	2/3	16°25'	168°24.2'	1,526.6	41.9
33	1	2/4	15°52.2'	169°54'	1,394.4	32.3
35	1	2/6	13°38'	164°55'	1,481.9	16.9
36	1	2/7	15°34'	163°14'	1,559.2	39.8
37	1	2/8	17°56'	160°57.2'	1,522.6	26.3
39	1	2/9	19°40'	159°31'	1,551.9	36.1

N= 27
Total= 679.0
$\bar{x}$= 25.14

1/ All hauls were oblique, from 60 m. to the surface, except those at stations 3B, 11B, and 24B. These three were oblique hauls from 140 m. to the surface; they were omitted in the averaging of sample weights.

2/ All hauls were made between 1900 and 2200 hours.

3/ Volumes determined as cc. /1,000 $m.^3$ have been converted to g. /1,000 $m.^3$. Jellies longer than 2 cm. and other organisms longer than 5 cm. are not included.

Table 14.--Zooplankton station positions and sample weights, *Hugh M. Smith* cruise 51

Station 1/	Sample	Date, 1959 2/	Position		Water strained $m.^3$	Weight (g./1,000 $m.^3$) 3/
			Lat. N.	Long. W.		
1	1	3/6	23°58.8'	155°00'	1,456.3	15.8
2	1	3/7	23°56.2'	152°48.8'	1,737.6	21.9
3	1	3/9	24°01.5'	148°32.8'	1,451.0	35.8
4	1	3/10	23°56'	146°30.5'	1,767.2	21.5
5	1	3/12	19°50.7'	146°52'	1,780.9	10.1
7	1	3/13	17°44'	147°42.8'	1,198.0	27.5
8	1	3/14	14°20.0'	149°06.5'	1,290.3	-- 4/
10	1	3/15	15°21.8'	150°49.8'	1,305.1	11.5
11	1	3/16	18°17'	153°15'	1,500.4	14.0
12	1	3/17	21°37'	153°50.8'	1,428.0	32.2
13	1	3/18	22°02'	155°54.2'	1,709.0	29.3
14	1	3/21	21°43.5'	159°19.5'	1,624.4	19.7
17	1	3/22	21°56.7'	161°26'	1,608.0	29.9
20	1	3/23	19°46.5'	160°48'	1,700.9	26.5
21	1	3/24	18°56.8'	159°01.2'	1,386.2	51.9
22	1	3/27	24°11'	151°32.5'	1,683.3	29.7
23	1	3/28	24°03.3'	148°43.2'	1,594.8	29.5
24	1	3/30	20°18'	145°29.2'	1,570.8	21.0
26	1	3/31	18°22.8'	147°09'	1,841.1	27.2
27	1	4/1	14°58'	149°28.2'	1,348.4	14.8
31	1	4/5	22°36'	156°14'	2,015.3	51.1

N=20
Total=520.9
$\bar{x}$=26.04

1/ All hauls were oblique, from 60 m. to the surface.

2/ All hauls were made between 1900 and 2200 hours.

3/ Volumes determined as cc. /1, 000 $m.^3$ have been converted to g. /1, 000 $m.^3$. Jellies longer than 2 cm. and other organisms longer than 5 cm. are not included.

4/ Sample almost entirely composed of salps; no weight taken.

Table 15.--Zooplankton station positions and sample weights, *Charles H. Gilbert* cruise 44

Station[1]	Sample	Date, 1959 [2]	Position		Water strained $m.^3$	Weight (g./1,000 $m.^3$)[3]
			Lat. N.	Long. W.		
3	1	4/30	22°31'	158°24'	1,453.8	36.5
4	1	5/1	23°50'	159°56'	1,417.5	15.5
6	1	5/2	21°58'	161°20'	1,808.2	39.8
7	1	5/3	19°34'	162°10'	1,197.2	15.9
9	1	5/4	19°34'	160°12'	1,520.1	23.0
10	1	5/9	21°42'	150°35'	2,013.2	15.9
11	1	5/10	18°45'	150°45.5'	1,548.6	23.9
13	1	5/11	16°31'	151°49.5'	1,599.6	11.3
14	1	5/12	18°11'	153°19'	1,817.1	29.7
15	1	5/13	21°06'	154°21.5'	1,218.6	15.6
17	1	5/14	23°01'	154°22'	1,575.4	25.4
19	1	5/15	23°11'	154°38'	1,648.3	15.8
20	1	5/16	20°03'	156°14.5'	1,758.0	9.1
21	1	5/17	18°23'	157°59.5'	1,613.1	23.6
23	1	5/23	20°24'	158°28'	1,501.4	32.6
24	1	5/21	18°03'	161°03'	1,458.3	13.7
26	1	5/23	23°07'	161°10'	1,196.0	31.8
27	1	5/24	23°49'	159°42'	1,663.1	22.2
29	1	5/26	22°02.5'	156°56.5'	1,598.3	45.7
30	1	5/27	24°26'	153°44'	1,557.0	26.3
31	1	5/28	22°01'	152°38'	1,367.1	41.7
32	1	5/30	18°13'	155°14'	1,364.3	11.7

N= 22
Total= 526.7
$\bar{x}$= 23.94

[1] All hauls were oblique, from 60 m. to the surface.

[2] All hauls were made between 1900 and 2200 hours.

[3] Volumes determined as cc. /1,000 $m.^3$ have been converted to g. /1,000 $m.^3$. Jellies longer than 2 cm. and other organisms longer than 5 cm. are not included.

Table 16.--Zooplankton station positions and sample weights, *Charles H. Gilbert* cruise 45

Station	Sample[1]	Date,[2] 1959	Position		Water strained $m.^3$	Weight ($g./1,000\ m.^3$)[3]
			Lat. N.	Long. W.		
12	1	7/17	20°18'	158°55'	1,449.3	11.7
	2	7/17	20°18'	158°55'	--	--
	3	7/17	20°18'	158°55'	--	--
13	1	7/18	18°15'	161°15'	1,128.6	32.8
	2	7/18	18°15'	161°15'	--	--
	3	7/18	18°15'	161°15'	--	--
14	1	7/19	20°40.1'	163°41.5'	1,033.7	40.6
	2	7/19	20°40.1'	163°41.5'	--	--
	3	7/19	20°40.1'	163°41.5'	--	--
15	1	7/20	23°20'	166°10'	1,055.2	37.0
	2	7/20	23°20'	166°10'	--	--
	3	7/20	23°20'	166°10'	--	--
19	1	7/22	24°25'	164°46'	1,341.0	34.3
	2	7/22	24°25'	164°46'	--	--
	3	7/22	24°25'	164°46'	--	--
21	1	7/23	25°38'	161°06'	1,245.4	16.9
	2	7/23	25°38'	161°06'	--	--
	3	7/23	25°38'	161°06'	--	--
22	1	7/24	23°07'	159°00'	810.7	82.6[4]
	2	7/24	23°07'	159°00'	--	--
	3	7/24	23°07'	159°00'	--	--
25	1	7/25	22°50'	156°20'	1,124.5	50.7
	2	7/25	22°50'	156°20'	--	--
	3	7/25	22°50'	156°20'	--	--
26	1	7/26	25°23'	153°33'	1,172.4	70.8
	2	7/26	25°23'	153°33'	--	--
	3	7/26	25°23'	153°33'	--	--
27	1	7/27	22°58'	152°52'	1,198.9	42.5
	2	7/27	22°58'	152°52'	--	--
	3	7/27	22°58'	152°52'	--	--
28	1	7/28	19°13'	152°55'	1,119.6	26.8
	2	7/28	19°13'	152°55'	--	--
	3	7/28	19°13'	152°55'	--	--
29	1	7/29	16°48.5'	154°37.5'	1,283.8	21.0
	2	7/29	16°48.5'	154°37.5'	--	--
	3	7/29	16°48.5'	154°37.5'	--	--
30	1	7/30	19°19'	157°11'	1,364.1	22.0

N = 12
Total = 407.1
$\bar{x}$ = 33.92

---

[1] Plankton hauls 2 and 3 for stations 12 through 29 were surface tows of 20 minutes' duration, for collecting larval tuna; weights were not determined. The remaining hauls were oblique from 60 m. to the surface.

[2] All hauls were made between 1900 and 2200 hours.

[3] Volumes determined as cc. /1,000 $m.^3$ have been converted to g. /1,000 $m.^3$. Jellies longer than 2 cm. and other organisms longer than 5 cm. are not included.

[4] Questionable value due to unusual abundance of salps; value not included in the averaging of sample weights.

Table 17.--Zooplankton station positions and sample weights, *Charles H. Gilbert* cruise 46

Station 1/	Sample 2/	Date, 1959 3/	Position		Water strained m.^{3}	Weight (g./1,000 m.^{3})4/
			Lat. N.	Long. W.		
11	A	10/1	17°13'	154°00'	1,476.4	16.9
11	B	10/1	17°13'	154°00'	1,439.6	16.0
13	A	10/2	17°54'	154°17'	1,587.0	18.3
13	B	10/2	17°54'	154°17'	1,571.5	20.4
14	A	10/3	21°18'	153°02'	1,646.9	23.1
14	B	10/3	21°18'	153°02'	1,634.7	35.5
16	A	10/4	22°48'	153°42'	1,525.2	31.5
16	B	10/4	22°48'	153°42'	1,465.6	36.2
17	A	10/8	20°48'	157°33'	1,831.1	2.6
17	B	10/8	20°48'	157°33'	1,698.8	7.0
17	C	10/8	20°48'	157°33'	1,473.9	6.2
17	D	10/8	20°48'	157°33'	1,455.1	3.8
17	E	10/8	20°48'	157°33'	1,336.7	5.2
18	A	10/8	20°21'	157°54'	1,423.1	24.6
18	B	10/8	20°21'	157°54'	1,404.9	25.0
21	A	10/10	15°33'	160°15'	1,421.1	11.3
21	B	10/10	15°33'	160°15'	1,464.8	13.0
22	A	10/11	17°06'	163°01'	1,403.0	27.8
22	B	10/11	17°06'	163°01'	1,589.1	22.7
23	A	10/12	18°08'	164°57'	1,397.3	19.3
23	B	10/12	18°08'	164°57'	1,408.7	18.5
24	A	10/14	20°42'	166°19'	1,497.0	16.0
24	B	10/14	20°42'	166°19'	1,504.6	21.9
25	A	10/15	21°10'	163°09'	1,666.7	24.6
25	B	10/15	21°10'	163°09'	1,524.4	25.6
26	A	10/17	21°51'	159°32'	1,652.3	24.2
26	B	10/17	21°51'	159°32'	1,442.8	33.3
26	C	10/17	21°51'	159°32'	1,617.6	23.5
26	D	10/17	21°51'	159°32'	1,382.9	27.5

N = 11
Total = 251.5
$\bar{x}$ = 22.86

1/ All hauls were oblique, from 60 m. to the surface, except at station 17, where five surface hauls were made.

2/ Samples other than "A" at each station were for serological studies of larval tuna.

3/ All hauls were made between 1900 and 2200 hours except at station 17, where the five surface hauls were made between 1207 and 1436.

4/ Volumes determined as cc. /1,000 m.^{3} have been converted to g. /1,000 m.^{3}. Jellies longer than 2 cm. and other organisms longer than 5 cm. are not included. Volumes of the five surface samples from station 17 were determined by R. S. Shomura. Total weight equals the average zooplankton weight at each station, with the exception of surface tows at station 17 which were not included.

Table 18.--Major zooplankton group composition of selected samples. Upper figure is number of individuals per 1,000 m.^{3} of water strained; lower figure is percentage of the sample

Cruise number	Station number	Chaetognatha	Siphonophora	Medusae	Annelida	Copepoda	Euphausiacea	Decapoda	Amphipoda	Pteropoda	Heteropoda	Crustacean eggs and larvae	Fish eggs and larvae	Ostracoda	Mysidacea	Salps	Appendicularia	Pelecypoda	Others
Hugh M. Smith 50	3A	2101 (11)	965 (5)	- -	- -	8289 (44)	1817 (2)	284 (0.9)	511 (3)	568 (3)	57 (0.3)	3132 (16)	114 (0.6)	227 (1)	- -	57 (0.3)	- -	114 (0.6)	- -
	22	3680 (13)	491 (2)	82 (0.3)	491 (2)	13330 (45)	981 (3)	572 (2)	409 (1)	1390 (5)	82 (0.3)	736 (3)	900 (3)	4252 (14)	82 (0.3)	327 (1)	- -	- (2)	246 (1)
	5	4232 (19)	441 (2)	88 (0.4)	- -	9345 (42)	2909 (13)	176 (0.8)	1146 (5)	1058 (5)	- -	1939 (9)	176 (0.4)	- -	88 (0.4)	88 (0.4)	- -	88 (0.4)	176 (0.8)
	28	385 (3)	48 (0.4)	- -	143 (1)	6643 (57)	1396 (12)	193 (2)	289 (2)	759 (7)	- -	- (5)	193 (2)	626 (5)	- -	95 (0.8)	- -	144 (1)	48 (0.8)
	35	283 (2)	283 (2)	- -	121 (0.8)	10128 (70)	688 (5)	40 (0.3)	364 (3)	1175 (8)	- -	505 (3)	- -	770 (5)	- -	- -	- -	- -	40 (0.3)
	19	1444 (15)	281 (3)	- -	120 (1)	4413 (44)	411 (4)	160 (2)	120 (1)	481 (5)	- -	682 (7)	- -	842 (8)	321 (3)	40 (0.4)	- -	40 (0.4)	160 (2)
Hugh M. Smith 51	20	353 (2)	494 (2)	71 (0.3)	282 (1)	11359 (54)	2751 (13)	71 (0.3)	1693 (8)	127 (0.7)	141 (0.7)	635 (3)	635 (3)	2751 (13)	71 (0.3)	282 (1.3)	- -	212 (1.0)	354 (2)
	17	1269 (4)	299 (1)	75 (0.3)	597 (2)	9179 (32)	1493 (5)	75 (0.3)	1343 (5)	1716 (5)	448 (2)	1652 (5)	286 (1)	9403 (33)	- -	- -	- -	300 (1)	- -
	23	677 (4)	226 (1)	38 (0.2)	- -	7374 (46)	1354 (9)	151 (1)	376 (2)	2257 (14)	- -	264 (2)	- -	2333 (15)	- -	75 (0.5)	- -	113 (0.7)	38 (0.2)
	27	712 (5)	89 (0.7)	- -	89 (0.7)	7476 (54)	1735 (13)	222 (2)	712 (5)	534 (4)	267 (2)	667 (5)	222 (2)	712 (5)	45 (0.3)	178 (1)	- -	- -	90 (0.7)
	4	272 (2)	407 (3)	68 (0.5)	- -	9370 (65)	747 (5)	204 (1)	272 (2)	951 (7)	- -	476 (3)	68 (0.5)	1222 (9)	- -	68 (0.5)	- -	68 (0.5)	204 (1)
Charles H. Gilbert 44	24	494 (4)	123 (1)	- -	- -	8681 (74)	247 (2)	- -	535 (5)	165 (1)	82 (0.7)	740 (6)	-1/ (1)	453 (4)	- -	123 (1)	- -	- -	41 (0.4)

1/ Eggs and larvae removed for chromatographic analysis, by W. M. Matsumoto.

Table 18.--Major zooplankton group composition of selected samples. Upper figure is number of individuals per 1,000 m.^{3} of water strained; lower figure is percentage of the sample (con.)

Cruise number	Station number	Chaetognatha	Siphonophora	Medusae	Annelida	Copepoda	Euphausiacea	Decapoda	Amphipoda	Pteropoda	Heteropoda	Crustacean eggs and larvae	Fish eggs and larvae	Ostracoda	Mysidacea	Salps	Appendicularia	Pelecypoda	Others
	29	2102 (8)	400 (1)	- -	225 (0.9)	14641 (55)	3228 (12)	150 (0.6)	1351 (5)	1126 (4)	375 (1)	300 (1.8)	- -	2177 (8)	75 (0.3)	375 (1)	- -	- -	- -
	21	149 (0.6)	74 (0.3)	- -	149 (0.6)	16887 (67)	967 (4)	- -	1711 (7)	595 (2)	446 (2)	- -	- -	3943 (16)	- -	74 (0.3)	- -	74 (0.3)	- -
	30	154 (0.6)	- -	- -	- -	16956 (68)	1696 (7)	- -	385 (2)	1618 (6)	54 (0.6)	2312 (9)	- -	1541 (6)	- -	- -	- -	154 (0.6)	- -
	31	527 (5)	44 (0.4)	- -	88 (0.9)	5925 (59)	1843 (18)	88 (0.9)	351 (3)	263 (3)	- -	- -	- -	702 (7)	- -	132 (1)	- -	44 (0.4)	44 (0.4)
Charles H. Gilbert 45	22	562 (3)	- -	- -	- -	4720 (23)	112 (0.6)	112 (0.6)	1686 (8)	- -	- -	1461 (7)	- -	1011 (5)	- -	10900 (53)	- -	- -	- -
	26	189 (0.7)	- -	- -	- -	19608 (73)	3221 (12)	379 (1)	758 (3)	- -	- -	1080 (3)	95 (0.4)	1516 (6)	- -	- -	- -	95 (0.4)	- -
	25	296 (1)	296 (1)	- -	99 (0.3)	15900 (54)	1778 (6)	395 (1)	1185 (4)	790 (3)	593 (2)	2370 (8)	888 (3)	3259 (11)	- -	1086 (4)	- -	- -	- -
	19	- -	- -	- -	- -	15239 (74)	1656 (8)	- -	911 (4)	497 (2)	- -	1490 (7)	166 (0.8)	414 (2)	- -	83 (0.4)	- -	- -	83 (0.4)
	14	322 (1)	322 (1)	- -	- -	13215 (55)	752 (3)	537 (2)	1826 (8)	1719 (7)	214 (0.9)	967 (4)	644 (3)	1826 (8)	- -	537 (2)	- -	322 (1)	644 (3)
Charles H. Gilbert 46	16A	1023 (6)	315 (2)	- -	- -	8655 (54)	629 (4)	236 (1)	315 (2)	1652 (10)	157 (0.9)	1179 (7)	157 (0.9)	865 (5)	- -	79 (0.5)	- -	- -	393 (3)
	11A	406 (4)	41 (0.4)	- -	122 (1)	6462 (67)	610 (6)	122 (1)	447 (5)	203 (2)	- -	365 (4)	203 (2)	366 (4)	- -	163 (2)	- -	- -	122 (1)
	13A	1248 (11)	76 (0.6)	- -	- -	6656 (58)	1134 (10)	- -	265 (2)	797 (7)	113 (1)	265 (2)	265 (2)	529 (5)	- -	114 (1)	- -	38 (0.3)	- -

Table 18.--Major zooplankton group composition of selected samples. Upper figure is number of individuals per 1,000 m.^{3} of water strained; lower figure is percentage of the sample (con.)

Cruise number	Station number	Chaetognatha	Siphonophora	Medusae	Annelida	Copepoda	Euphausiacea	Decapoda	Amphipoda	Pteropoda	Heteropoda	Crustacean eggs and larvae	Fish eggs and larvae	Ostracoda	Mysidacea	Salps	Appendicularia	Pelecypoda	Others
	21A	549 (7)	84 (1)	- -	253 (3)	4855 (59)	929 (11)	- -	464 (6)	422 (5)	84 (1)	169 (2)	127 (2)	253 (3)	- -	84 (1)	- -	- -	- -
	18A	1602 (8)	590 (3)	- -	- -	5650 (28)	944 (46)	337 (2)	506 (3)	675 (3)	- -	253 (1)	253 (1)	506 (3)	84 (0.4)	253 (1)	- -	169 (0.8)	169 (0.8)

Table 19.--Record of surface fish school, bird flock, and aquatic mammal sightings, *Hugh M. Smith* cruise 50

Date, 1959	Time LZT	Position		Bird flock sightings[1]	Surface Fish Schools			Aquatic mammals
		Lat. N.	Long. W.		Species	Size of fish (lbs.)	Size of school	
1/10	0905	18°38'	155°45'	X (18)	Skipjack	6	Small	-
	1240	18°14'	155°22'	X (4)	?[2]	-	-	-
	1420	18°04'	155°13'	-	-	-	-	1 Whale
	1500	17°58'	155°08'	-	-	-	-	1 Whale
	1550	17°53'	155°04'	-	-	-	-	1 Whale
	1610	17°50.5'	155°01.5'	-	-	-	-	4 Whales
	1800	17°41'	154°51'	-	-	-	-	1 Whale
1/12	1607	12°46'	150°41'	X (10)	?	-	-	-
1/15	1120	17°16'	149°17.5'	-	Skipjack	5	-	-
1/19	1055	16°41'	147°13'	-	-	-	-	1 Whale
1/23	1355	20°49'	150°55'	-	-	-	-	2 Whales
1/24	1400	19°08.5'	153°09'	X (21)	?	-	-	-
1/27	0920	20°40'	154°22.5'	X (65)	Yellowfin	15	-	-
1/28	1210	18°50'	155°34'	X (152)	Skipjack	8	-	-
	1330	18°43'	155°43'	-	Skipjack	6	-	-
	1415	18°37'	155°50.5'	X (250)	?	-	-	-
1/29	0848	17°56'	158°06'	X (20)	?	-	-	-
1/30	0720	19°17.5'	160°40'	-	Skipjack	Small	-	-
	0800	19°19'	160°49'	-	-	-	-	1 Whale
	0950	19°29'	161°03'	-	Skipjack	6	-	-
	1027	19°32'	161°07.5'	-	?	Small	-	-
	1125	19°36'	161°17'	X (15)	Skipjack	11	-	-
	1215	19°47'	161°30'	-	-	-	-	1 Whale
	1415	20°02.5'	161°47'	X (10)	Skipjack	3-4	-	-
1/31	1450	22°15'	162°43'	X (30)	Skipjack	8	-	-
	1500	22°16'	162°43'	-	-	-	-	1 Whale
2/4	1200	16°22'	170°31'	-	-	-	-	1 Whale
2/5	0820	14°58'	168°33'	X (20)	?	-	-	-
2/6	0850	14°56'	168°29'	X (9)	?	Small	-	-
2/8	1550	17°27'	161°18'	X (25)	?	-	-	-
2/9	1710	19°20'	159°50'	X (15)	Skipjack	-	-	-
2/10	1740	21°01.5'	158°16'	-	Skipjack	2-3	Small	-

[1] X = Bird flock.
( ) = Number birds in flock.
[2] ? = Species not determined.

Table 20.--Record of surface fish school, bird flock, and aquatic mammal sightings, *Hugh M. Smith* cruise 51

Date, 1959	Time LZT	Position		Bird flock sightings[1]	Surface Fish Schools			Aquatic mammals
		Lat. N.	Long. W.		Species	Size of fish (lbs.)	Size of school	
3/5	1740	21°37'	156°16'	X (150)	Skipjack	-	Large	-
3/6	1020	23°01'	155°27'	X (50)	?[2]	-	-	-
3/12	1315	20°49'	146°29'	-	-	-	-	2 Porpoises
3/13	1745	18°05'	147°35'	-	-	-	-	4 Porpoises
3/14	0945	15°48'	148°35'	X (10)	?	-	-	-
	1420	15°10'	148°45'	-	-	-	-	4 Whales
3/15	0915	14°48'	150°13'	X (15)	?	-	-	-
3/18	1210	22°34'	155°00'	X (60)	Skipjack	20	Large	-
	1535	22°25'	155°20'	X (75)	Skipjack	6-7	Large	-
	1540	22°25'	155°20'	X (25)	Skipjack	6	-	-
3/19	0700	21°21'	157°34'	X (50)	?	-	-	-
	0755	21°16'	157°42'	-	-	-	-	2 Whales
3/21	1720	21°35'	158°58'	X (15)	?	-	-	-
	1125	21°16'	157°54'	-	-	-	-	2 Sperm whales
3/22	0752	22°34'	161°04'	X (150)	?	-	-	-
	0850	22°44'	161°15'	X (7)	?	-	Small	-
	0955	22°45'	161°29'	X (15)	?	-	Small	-
	1000	22°45.5'	161.30'	X (8)	?	-	Small	-
	1036	22°58'	161°38'	-	-	-	-	3 Porpoises
	1045	22°57'	161°39'	X (12)	?	-	Small	-
	1055	22°57'	161°40'	X (15)	?	-	Medium	-
	1211	22°59'	161°48'	X (9)	-	-	-	1 Sperm whale
	1255	22°53'	161°47'	X (15)	Skipjack	1-2	Small	-
	1325	22°48'	161°44'	X (75)	Skipjack	4-5	Large	-
3/23	0810	20°29'	161°06'	X (40)	Skipjack	-	-	-
	1120	20°29'	161°06'	X (40)	Skipjack	-	Small	-
	1135	20°29'	161°06'	X (50)	Skipjack	-	Large	-
	1625	20°21'	161°00'	X (75)	?	-	Large	-
	1651	20°17'	160°58'	X (90)	?	-	Large	-
	1705	20°16'	160°58'	X (70)	?	-	-	-
3/24	1510	18°24'	159°39'	X (30)	Skipjack	8	Small	-
	1535	18°26'	159°36'	X (50)	Skipjack	18-20	Large	-
3/25	0650	19°56'	157°46'	X (15)	Skipjack	6	Small	-
	1548	20°46.5'	157°10'	X (50)	?	-	-	-
3/26	0728	21°32'	155°50'	X (10)	-	-	-	-
	1622	22°15'	154°58'	X (25)	?	-	-	-
	1750	22°22'	154°50'	X (150)	?	-	-	-
	1832	22°25'	154°46'	X (75)	?	-	-	-
3/27	1708	23°57'	151°58'	-	-	-	-	1 Whale
	1720	23°59'	151°56'	X (30)	Skipjack	4	Small	-
3/28	1215	24°11'	149°31'	-	-	-	-	1 Whale
4/1	1255	16°01'	148°44'	X (30)	-	-	-	-
	1540	15°39'	149°00'	X (40)	?	-	-	-
4/3	1614	19°49'	152°23'	X (150)	?	-	-	-
4/5	1345	23°25'	155°31'	X (60)	Skipjack	8	Large	-
	1615	23°05'	155°47.5'	X (40)	Skipjack	7	Medium	-
	1625	23°04'	155°48'	X (30)	?	-	Small	-
4/6	0730	21°37'	157°23'	X (40)	Skipjack	8	Medium	-
	0745	21°35'	157°25'	X (150)	Skipjack	8-12	Large	-
	0750	21°34'	157°26'	X (100)	?	-	Large	-
	0915	21°21'	157°36'	X (150)	?	-	Large	-

[1] X = Bird flock.
( ) = Number birds in flock.

[2] ? = Species not determined.

Table 21.--Record of surface fish school, bird flock, and aquatic mammal sightings, Charles H. Gilbert cruise 44

Date, 1959	Time LZT	Position		Bird flock sightings[1]	Surface fish schools			Aquatic mammals
		Lat. N.	Long. W.		Species	Size of fish (lbs.)	Size of school	
4/30	1220	21°39'	158°18'	X (50)	?[2]	-	Medium	-
	1010	21°30'	158°18.5'	X (25)	-	-	-	-
	1345	21°47'	158°20'	X (175)	?	-	Large	-
	1450	21°51.5'	158°22'	X (180)	Skipjack	6-8	?	-
5/1	1220	24°06'	158°45'	X (75)	?	?	?	-
	1310	24°05'	159°02'	-	-	-	-	-
5/2	1705	22°17'	161°06'	X (20)	-	-	-	-
5/3	0908	20°26'	162°33'	-	?	?	Small	-
5/5	1100	20°12.5'	162°44'	X (200)	?	?	Large	-
	1245	20°00'	162°54'	-	-	-	-	-
	1215	20°02'	162°51'	X (75)	?	-	Small	-
	1230	20°01'	162°53'	X (75)	?	-	Small	-
5/6	1505	21°18'	157°31'	X (45)	Skipjack	6	-	-
	1525	21°31'	157°29'	X (150)	Skipjack	-	-	-
	1720	21°42'	157°21'	X (150)	Skipjack	-	-	-
5/15	1345	23°57'	154°16'	-	-	-	-	1 Porpoise
5/16	1150	21°11'	155°38'	-	-	-	-	-
	1305	21°01'	155°43'	X (100)	Skipjack	3-4	Medium	-
	1547	20°36'	155°54'	X (40)	?	-	Small	-
	1615	20°32'	155°56'	X (75)	?	-	Small	-
	1820	20°15'	156°06'	X (50)	?	-	Small	-
5/18	0823	20°06'	157°56'	X (50)	-	-	-	-
	1235	20°47'	157°54'	X (150)	?	-	Medium	-
	1350	20°54'	157°57'	X (160)	?	-	Medium	-
5/20	1125	21°03.5'	158°10'	X (100)	?	-	-	-
	1350	21°00'	158°14'	X (150)	?	-	-	-
	1730	20°40'	158°32'	X (40)	Skipjack	2	-	-
	0930	21°14'	157°56'	-	-	-	-	-
5/21	0910	19°02'	159°47'	-	-	-	-	20 Porpoise school
5/22	1755	20°49'	161°07'	X (75)	?	-	-	-
5/23	1200	22°35'	160°37'	-	-	-	-	-
	0710	22°21'	160°55'	X (200)	Skipjack	-	-	-
	0910	22°21'	160°46'	X (150)	Skipjack	15	Medium	-
	1215	22°36.5'	160°37'	X (50)	?	-	?	-
5/24	1232	24°29'	160°38'	X (30)	Skipjack	12-15	Small	-
5/25	1030	22°10'	158°04'	X (50)	Skipjack	3	Small	-
	0640	22°37'	158°28'	-	-	-	-	2 Whales
5/26	1410	21°36'	157°32'	X (40)	Skipjack	-	Small	-
	1435	21°43'	157°30'	X (50)	Skipjack	-	Small	-
	1720	21°50'	157°18'	X (200)	?	-	-	-
	1750	21°52'	157°13'	X (75)	?	-	-	-
	1815	21°55'	157°10.5'	X (75)	?	-	-	-
5/27	0725	23°08'	155°26'	X (50)	Skipjack	8-12	Medium	-
	0805	23°12'	155°26'	X (50)	?	Small	Small	-
	0855	23°18'	155°20'	X (30)	?	-	Small	-
	1320	23°45'	154°44'	-	-	-	-	(?)Porpoise school
5/31	0743	19°17'	156°04'	-	-	-	-	50 Porpoise school

[1] X = Bird flock.
( ) = Number birds in flock.

[2] ? = Species not determined.

Table 22.--Record of surface fish school, bird flock, and aquatic mammal sightings, *Charles H. Gilbert* cruise 45

Date, 1959	Time LZT	Position		Bird flock sightings[1/]	Surface fish schools			Aquatic mammals		Other
		Lat. N.	Long. W.		Species	Size of fish (lbs.)	Size of school	Whales	Porpoise	
7/7	1215	21°24'	158°12'	X (100)	Skipjack	Medium	Medium			
	1305	21°24'	158°16'	X (150)	Skipjack	4-5	Large			
	1450	21°24'	158°16'	X (75)	Skipjack	6	Medium			
7/8	0950	21°23'	158°17'	X (200)	Skipjack	22-25	-			
7/9	0820	21°09'	157°47'	X (75)	?[2/]	-	Medium			
	0843	21°08'	157°46'	X (100)	?	-	-			
	0910	21°07'	157°45'	X (250)	?	-	Medium			
	1010	21°02'	157°45'	X (500)	?	-	-			
	1050	21°01'	157°43'	X (500)	Skipjack	18	Medium			
	1205	21°02'	157°29'	-	-	-	-			
	1225	21°06'	157°38'	X (100)	?	-	-			
	1240	21°07'	157°38'	X (1000)	Skipjack	-	-			
	1610	21°10'	157°48'	X (150)	Skipjack	4	Medium			
	1705	21°06'	157°48'	X (75)	?	-	Small			
	1725	21°04'	157°46.5'	X (1000)	?	-	-			
	1810	21°03'	157°46'	X (1000)	Little Tunny	-	-			
7/10	1003	21°07'	157°44'	X (375)	?	-	Large			
	1032	21°06'	157°45'	X (100)	-	-	-			
	1040	21°05'	157°45'	X (350)	?	-	Large			
7/12	1206	21°12'	158°14'	X (75)	Skipjack	20	Medium			
	1206	21°12'	158°14'	X (75)	Skipjack	20	Medium			
	1316	21°18'	158°07'	X (30)	Yellowfin	-	Small			
7/13	0755	21°29.5'	158°16'	X (30)	Yellowfin	-	Small			
	0805	21°29.5'	158°18'	X 950)	?	-	Small			
	0925	21°26'	158°29'	-	Yellowfin	-	-			
	1135	21°19'	158°22'	X (50)	Skipjack	3-5	Medium			
	1355	21°15'	158°16'	-	-	-	-			
7/14	0925	21°15'	158°12'	X (25)	?	-	Small			
	0945	21°14'	158°13'	X (30)	?	-	Small			
	1128	21°26'	158°20'	-	-	-	-			200 FF*
	1148	21°29'	158°20'	X (40)	Skipjack	-	-			
	1315	21°27'	158°17'	X (40)	-	-	-			
7/17	1344	20°59'	158°12'	X (150)	Skipjack	15-20	-			
7/18	0637	19°11'	159°50'	X (75)	-	-	-			300 FF*
	0810	19°01'	159°58'	- (100)	-	-	-			
	1050	18°42'	160°19'	X (125)	-	-	-			
	1121	18°34.5'	160°18'	X (125)	-	-	-			
	1420	18°18'	160°37'	X (75)	?	-	Medium			
	1450	18°16.5'	160°39'	X (75)	?	-	Medium			300 FF*
	1635	18°06'	160°50'	X (100)	?	-	-			
	1745	17°59'	160°59'	X (300)	?	-	Large			

1/ X = Bird flock.
( )= Number birds in flock.

2/ ? = Species not determined.
* Flying Fish.

Table 22.--Record of surface fish school, bird flock, and aquatic mammal sightings, *Charles H. Gilbert* cruise 45 (con.)

Date, 1959	Time LZT	Position		Bird flock sightings1/	Surface fish schools			Aquatic mammals		Other
		Lat. N.	Long. W.		Species	Size of fish (lbs.)	Size of school	Whales	Porpoise	
	1848	18°06'	161°07'	X (75)	? 2/	-	-			
	1917	18°08'	161°10'	X (100)	?	-	-			
7/19	0730	19°12'	162°24'	X (200)	Skipjack	18	Large			
	1020	19°30'	162°42'	X (200)	?	-	Large			
	1045	19°32'	162°44'	X (3000)	Skipjack	18	Large			100 FF*
	1125	19°36'	162°49'	X (100)	?	-	Medium			200 FF*
	1245	19°45'	162°57'	X (150)	?	-	-			
	1335	19°50'	163°01.5'	X (100)	Skipjack	-	-			
	1400	19°53.5'	163°04'	X (200)	?	-	Large			
	1445	19°59'	163°08'	X (30)	?	-	Small			
	1530	20°04'	163°13'	X (100)	?	20	Large			
	1540	20°05'	163°13'	X (150)	?	-	Large			
	1701	20°14'	163°21'	X (100)	?	-	Large			
	1710	20°15.5'	163°22'	X (50)	?	-	Small			
	1754	20°21'	163°27'	X (75)	-	-	Medium			
7/20	0823	21°55.5'	164°50'	X (300)	?	-	Large			
	0932	22°09'	165°02'	X (30)	?	-	Small			
	1120	22°14'	165°07'	X (75)	?	-	Medium			
7/22	1358	24°08.5'	165°47'	X (75)	Skipjack	4-6	Small			
7/23	1010	25°11'	162°43'	-	Skipjack	2-3	Small			
	1300	25°19'	162°15'	-	-	-	-			
	1740	25°31'	161°31'	-	-	-	-		School	
7/24	1835	23°22'	159°11'	X (15)	Skipjack	3-5	-			
7/25	0700	22°04'	157°51'	-	-	-	-			
	1005	22°19'	157°25'	X (100)	Skipjack	30	Medium			
	1410	22°27'	157°12'	-	Skipjack	30	Medium			
7/27	1345	23°46'	152°45'	X (7)	Skipjack	30	Small			
	1450	23°37'	152°44'	X (75)	Skipjack	-	Medium			
7/28	0845	21°00'	152°40'	X (15)	?	-	Small			
	1315	20°17'	152°42'	X (50)	?	-	Small			
	1550	19°42'	152°43'	-	-	-	-			
7/29	1738	16°52'	154°19.5'	-	-	-	-			150 FF*
7/30	0708	17°21'	156°11'	X (100)	Skipjack	10-12	Medium			
	0825	17°31'	156°16'	-	-	-	-	1		
	0833	17°32'	156°17'	X (150)	?	-	Large			
	1030	17°51'	156°26'	X (25)	?	-	Small			
	1108	17°57'	156°29.5'	X (75)	?	-	Small			
	1217	18°08'	156°34.5'	X (15)	-	-	-			
	1230	18°10'	156°36'	X (100)	?	-	-			
	1526	18°37'	156°49'	X (50)	?	-	Small			
	1600	18°42'	156°51.5'	X (200)	?	-	Large			
	1625	18°45'	156°53'	X (150)	?	-	Large			

1/ X = Bird flock.
( )= Number birds in flock.

2/ ? = Species not determined.
* Flying Fish.

Table 22.--Record of surface fish school, bird flock, and aquatic mammal sightings, Charles H. Gilbert cruise 45 (con.)

Date, 1959	Time LZT	Position		Bird flock sightings[1/]	Surface fish schools			Aquatic mammals		Other
		Lat. N.	Long. W.		Species	Size of fish (lbs.)	Size of school	Whales	Porpoise	
8/2	0900			X (75)	? [2/]	40	Small			
	0920			X (500)	Yellowfin	40	Small			
	1050			X (35)	?	-	Small			
	1113			X (75)	Yellowfin	50	Small			
	1436			X (50)	?	-	Small			
	1620			X (40)	-	-	-			
	1630			X (500)	Skipjack	6	Large			
8/3	0910			X (350)	?	-	Large			
	1143			X (200)	Skipjack	10	Large			
	1455			X (100)	?	-	-			
	1603			X (300)	Skipjack	-	Large			
8/4	0806			X (50)	?	-	-			
	0810			X (50)	?	-	-			
	0920			X (50)	?	-	-			
	0958			X (50)	Skipjack	-	Small			
	1114			X (50)	Skipjack	25	Large			
	1125			X (50)	?	-	Large			

[1/] X = Bird flock.
( ) = Number birds in flock.
[2/] ? = Species not determined.

Table 23.--Record of surface fish school, bird flock, and aquatic mammal sightings
Charles H. Gilbert cruise 46

Date, 1959	Time LZT	Position		Bird flock sightings[1]	Surface Fish Schools			Aquatic mammals
		Lat. N.	Long. W.		Species	Size of fish (lbs.)	Size of school	
9/29	1130	20°32'	157°30'	X (200)	?[2]	-	-	-
10/1	0825	17°35'	155°16'	X (50)	Dolphin	-	-	-
10/3	1620	20°46'	153°04'	X (30)	-	-	-	-
10/7	0645	21°13'	157°42'	X (36)	-	-	-	-
10/8	0920	21°03'	157°27'	X (50)	?	-	-	-
	1055	20°55'	157°25'	X (40)	?	-	-	-
	1115	20°52'	157°27'	X (70)	?	-	-	-
	1510	20°59'	157°24'	X (200)	?	-	Medium	-
	1604	20°51'	157°30'	X (150)	?	-	-	-
10/9	0810	18°59'	158°52'	X (50)	-	-	-	-
	0930	18°50'	159°02'	X (30)	-	-	-	-
	0945	18°49'	159°04'	X (30)	-	-	-	-
	1000	18°47'	159°06'	X (150)	Skipjack	10-18	Large	-
	1450	18°22.5'	159°34'	X (30)	Skipjack	-	Small	-
	1510	18°20'	159°34'	X (30)	?	-	Small	-
	1810	18°05'	159°54'	X (200)	Skipjack	Mixed	Large	-
10/11	1330	16°34'	162°10'	X (50)	?	-	-	-
	1721	16°53'	162°43'	X (150)	Skipjack	10-15	Large	-
10/12	1404	18°46'	164°15.5'	X (75)	?	-	-	-
10/13	0915	16°45'	166°17'	-	-	-	-	1 Whale
	0957	16°40'	166°23'	X (18)	-	-	-	-
10/14	1050	19°58'	167°22'	X (16)	-	-	-	-
10/15	1035	20°14'	164°07'	X (15)	-	-	-	-
10/16	1130	22°38'	161°57'	X (110)	-	-	-	-
10/17	1125	22°02'	160°02'	-	-	-	-	50 Porpoise
	1416	22°10'	159°48'	-	-	-	-	School porpoise
	1425	22°13'	159°47'	X (100)	Yellowfin	-	Medium	-
	1530	22°16'	159°45.5'	X (250)	-	-	-	-
10/18	1006	21°31'	158°18'	-	-	-	-	8 Porpoise

[1] X = Bird flock.
( ) = Number birds in flock.
[2] ? = Species not determined.

Table 24.--Summary of longline catch data

Cruise	Station	Date, 1959	Position		Skipjack	Yellowfin	Bigeye Tuna	Dolphin	Wahoo	Striped Marlin	Black Marlin	Marlin	Sailfish	Shortnosed Spearfish	Great Blue Shark	Silky Shark	Whitetip Shark	*Mackerel Shark	Shark (Sp.)	Lancet Fish	Puffer	Total
			Lat. N.	Long. W.																		
Hugh M. Smith 50	4	1/13	12°50.5'	149°41'		2		5	1			2			2	1	1					14
	6	1/14	15°08'	149°37'				2	1									1				4
	8	1/15	17°16'	149°17.5'			3	2														5
	10	1/16	16°39'	147°11'				16				1		2	1							20
	14	1/20	21°02'	148°00'						2												2
	16	1/21	23°02'	148°03'				7											1			8
	18	1/22	24°32'	149°15'	3			11		1					1							16
	23	1/26	22°47'	153°05'			1	2	1						1						1	6
	29	2/2	18°48'	165°49'				3		1					1							5
	32	2/4	16°23'	170°03'																1		1
	38	2/9	19°10'	160°03'			2			3					3							8
				TOTAL	3	2	6	48	3	7		3		2	9	1	1	1	1	1	1	89
Hugh M. Smith 51	6	3/13	18°23.5'	147°31'		3	3	5	1					3					2			17
	9	3/15	14°48'	150°13'		1	3	5		2												11
	18	3/23	20°29'	161°06'			1	3											5			9
	25	3/31	19°03'	146°34'			1	1		1										1		4
	28	4/2	16°24'	150°22'				3														3
	29	4/4	21°47'	153°25'			1	2		1									3			7
				TOTAL		4	9	19	1	4				3					10	1		51
Charles H. Gilbert 44	5	5/2	22°27'	161°02'		1			1	2												4
	8	5/4	19°07'	160°56'						1												1
	12	5/11	17°17.5'	151°29'						1	1				1		2					5
	16	5/14	22°19'	154°25'													1					1
	18	5/15	24°04.5'	154°19'				1	1													2
				TOTAL		1		1	2	4	1				1		3					13
Charles H. Gilbert 46	12	10/2	17°00'	153°25'		1	2	1							2		2			1		9
	15	10/4	22°52'	152°57'				2		1					1		1					5
	20	10/10	16°25'	160°15'	1			1					2		1		1					6
				TOTAL	1	1	2	4		1			2		4		4			1		20

* Not positively identified. Described in Longline Fishing Log as having blue pointed snout, large teeth and dark spots on ventral surface.

Table 25.--Summary of surface trolling catch data

Cruise	Date, 1959	Time LZT	Position		Catch Species	Catch Number
			Lat. N.	Long. W.		
Hugh M. Smith 50	1/10	0940	18°34'	155°40'	dolphin	1
	1/10	1310	18°12'	155°21'	"	1
	1/11	0820	16°03'	153°30'	"	1
		0825	16°02'	153°28'	bigeye	1
	1/13	1000	12°50'	149°38'	dolphin	1
		1215	12°51'	149°39'	"	1
	1/15	1225	17°14.5'	149°00'	"	1
	1/16	0900	16°43'	147°20.5'	dolphin	1
	1/20	0925	21°02'	148°00'	"	1
	1/24	1400	19°09'	153°09'	"	1
	1/27	0925	20°40.5'	154°22.5'	"	1
	1/29	0900	18°00'	158°06'	"	1
	2/6	1745	14°24'	167°30.5'	"	1
	2/7	0930	14°40'	164°0.8'	"	1
		1610	15°16'	163°36'	"	1
Hugh M. Smith 51	3/6	1705	23°41'	155°11'	"	1
		1800	23°47'	155°08'	"	1
	3/14	1150	15°27'	148°39'	"	3
	3/16	0925	16°55'	152°13.5'	"	1
					wahoo	2
	3/26	1400	22°05'	155°12'	dolphin	1
		1530	22°12'	155°04'	"	1
	3/27	1530	23°51'	152°11'	"	2
	3/29	0950	23°32'	147°29'	"	1
Charles H. Gilbert 44	5/1	1310	24°05'	159°02'	"	1
	5/5	1245	20°00'	162°54'	"	2[1]
	5/16	0945	21°30'	155°29.5'	"	1
	5/20	1155	21°04'	158°09'	"	2
	5/23	1040	22°25'	160°36.5'	wahoo	1
Charles H. Gilbert 45	7/23	1300	25°19'	162°15'	dolphin	-[2]
	7/25	0700	22°04'	157°51'	"	1
	7/28	1500	19°42'	152°43'	"	1
Charles H. Gilbert 46	10/1	0830	17°36'	155°17'	"	1
		1100	17°35'	155°04'	"	2
	10/13	1812	17°32'	167°01'	"	2
	10/15	1525	20°38'	163°39'	"	1
		1555	20°42'	163°31'	"	1

[1] Sighted from vessel, not caught.

[2] "A few," sighted from vessel near floating log.

Table 26.--Summary of skipjack tagging

Cruise	Date, 1959	Position		Number tagged	Average size (cm.)
		Lat. N.	Long. W.		
Hugh M. Smith 51	3/22	22°48'	161°45'	11	42.7
	3/22	22°21'	161°35'	40	44.4
	3/23	20°30'	161°31'	5	63.7
Charles H. Gilbert 44	5/23	22°20'	160°55'	7	61.1
	5/25	22°10'	158°04'	29	41.6
Charles H. Gilbert 45	7/25	22°31'	157°03'	76	76.4
	8/19	21°18'	158°13'	14	47.8
Charles H. Gilbert 46	10/9	18°41'	159°14'	54	65.0
				236	

Table 27.--Common and scientific names of fishes reported

Common Name	Scientific Name
Mackerel Shark	*Lamna ditropis* (Hubbs and Follett)
Great Blue Shark	*Prionace glauca* (Linnaeus)
Silky Shark	*Eulamia floridanus* (Bigelow, Schroeder, and Springer)
Whitetip Shark	*Pterolamiops longimanus* (Poey)
Lancet Fish	*Alepisaurus* sp.
Flying Fish	*Exocoetidae*
Skipjack	*Katsuwonus pelamis* (Linnaeus)
Bigeye Tuna	*Parathunnus sibi* (Temminck and Schlegel)
Yellowfin	*Neothunnus macropterus* (Temminck and Schlegel)
Wahoo	*Acanthocybium solandri* (Cuvier and Valenciennes)
Shortnosed Spearfish	*Teptrapturus angustirostris* Tanaka
Marlin	*Makaira* sp.
Black Marlin	*Istiompax marlina* (Jordan and Hill)
Striped Marlin	*Makaira audax* (Philippi)
Sailfish	*Istiophorus orientalis* (Temminck and Schlegel)
Dolphin	*Coryphaena hippurus* Linnaeus
Puffer	*Lagocephalus lagocephalus* (Linnaeus)

DISTRIBUTION AND ABUNDANCE OF SKIPJACK IN THE HAWAII FISHERY, 1952–53

By HERBERT H. SHIPPEN

FISHERY BULLETIN 188
From Fishery Bulletin of the Fish and Wildlife Service
VOLUME 61

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES

UNITED STATES DEPARTMENT OF THE INTERIOR, Stewart L. Udall, *Secretary*
FISH AND WILDLIFE SERVICE, Clarence F. Pautzke, *Commissioner*
BUREAU OF COMMERCIAL FISHERIES, DONALD L. MCKERNAN, *Director*

DISTRIBUTION AND ABUNDANCE OF SKIPJACK IN THE HAWAII FISHERY, 1952–53

By HERBERT H. SHIPPEN

March 3, 1849

FISHERY BULLETIN 188
From Fishery Bulletin of the Fish and Wildlife Service
VOLUME 61

Published by the U.S. Fish and Wildlife Service • Washington • 1961
Printed at the U.S. Government Printing Office, Washington, D.C.

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. - Price 20 cents

Library of Congress catalog card for the series, Fishery Bulletin of the Fish and Wildlife Series:

U.S. *Fish and Wildlife Service.*
Fishery bulletin. v. 1–
Washington, U.S. Govt. Print. Off., 1881–19

v. in illus., maps (part fold.) 23–28 cm.

Some vols. issued in the congressional series as Senate or House documents.
Bulletins composing v. 47– also numbered 1–
Title varies: v. 1–49, Bulletin.
Vols. 1–49 issued by Bureau of Fisheries (called Fish Commission, v. 1–23)

1. Fisheries—U. S. 2. Fish-culture—U. S. I. Title.

SH11.A25 639.206173 9–35239 rev 2*

Library of Congress [r55e¾]

CONTENTS

Page

Hawaii skipjack fishery 281
- Purposes of this study 281
- Utilization of data 282
- Choice of unit of fishing effort 282

Sources of error 286
- Error in determination of fish size 286
- Error in estimation of fishing effort 287
- Other sources of error 287
- Conclusions on sources of error 287

Results and discussion 287
- Geographical distribution of 1952 and 1953 catches 288
- Catch per unit-of-effort in the Hawaii skipjack fishery 288
- Size of skipjack and pounds caught per unit of effort 289
- Distribution of 1952 and 1953 catches by biweekly periods 292
  - Catches for the entire fishery 292
  - Effects of small craft warnings 292
- Movements of skipjack within the fishery 292
  - Large skipjack 294
  - Small skipjack 294

Oahu skipjack fishery, 1952 and 1953 294
- Statistical comparisons 294
- Relationships between catch statistics 294
- Use of catch records to determine population composition 295
  - Fluctuations in the catch of large skipjack in the Oahu region 296
  - Size composition 297
  - Conjecture 297

Summary 300

Literature cited 300

ABSTRACT

Commercial catch records of the Hawaii skipjack fishery for 1952 (a poor year) and 1953 (a good year) are summarized by area and time of catch and by size composition. A unit of fishing effort and its appropriateness are discussed. Geographical distribution of the catch and effort is determined and the two years are compared. Movements of skipjack throughout the fishery are analyzed. The usefulness of the raw catch and the catch per unit of effort as indexes of abundance are considered, and some conjectures as to the nature of the population supporting the fishery are offered.

DISTRIBUTION AND ABUNDANCE OF SKIPJACK IN THE HAWAII FISHERY, 1952–53

By **Herbert H. Shippen**, *Fishery Research Biologist*,
Bureau of Commercial Fisheries

A study of the environmental factors that may nfluence the availability of the skipjack (*Katsu-onus pelamis*) to the Hawaii fishery was begun y the staff of the U.S. Fish and Wildlife Service iological Laboratory (Honolulu, Hawaii). Be-ause the index of availability is to be based on ecords of commercial skipjack landings, an analys of these records is an essential part of this udy.

HAWAII SKIPJACK FISHERY

The skipjack, or aku, is the most important comercial species of fish in Hawaii, both in terms of uantity landed and dollar value. The 11 million ounds caught and sold for $1,260,000 in 1956 conituted about 70 percent of the total catch of arine species and 40 percent of the value received y Hawaii fishermen during that year. Most of e catch is canned, but a small amount, estimated t less than 10 percent, is sold fresh.

June (1951) and Yamashita (1958) have deribed the fishery in some detail. Since World ar II, the skipjack fleet has consisted of approxiately 15 to 20 sampans based in Honolulu, with few boats based at the islands of Kauai, Maui, nd Hawaii. A sampan usually carries a crew of to 15 men. The fishermen rely on the presence f flocks of wild birds to locate skipjack schools. he fish are caught on pole-and-line after being tracted to the boat by chumming with live bait.

The fishery is seasonal with large catches generly occurring in the summer and small catches in e winter months. Catches have fluctuated idely in recent years (fig. 1). The skipjack ken weigh from 2 to 30 pounds. The most ught after size is the 17- to 22-pound fish, known the fishermen as "season fish." Brock (1954, p. 96) estimates these to be either in their second or third year of life. The reason for the seasonal fluctuation in the catch appears to be the migration of season fish into and out of the area of the fishery, but the direction and significance of this migration in the life history of the species are largely unknown.

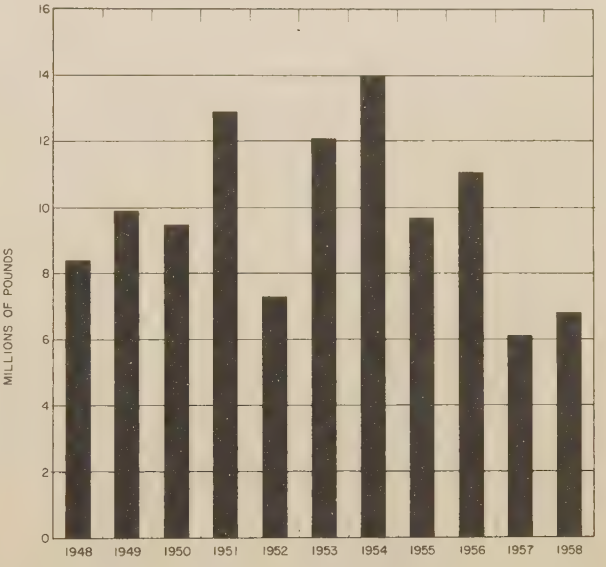


Figure 1.—Annual Hawaii skipjack catch, 1948–58.

PURPOSES OF THIS STUDY

The purposes of this study are (1) to examine the raw catch data and the catch per unit of effort as measures of the apparent abundance of skipjack; (2) to search the data for differences between good and poor years in the fishery; (3) to study movements of skipjack within the fishery during the course of the season; (4) to examine the distribution of pounds of skipjack caught, catch per unit of effort, total effort, and size composition of the catch throughout the fishery.

NOTE.—Approved for publication February 24, 1961. Fishery lletin 195.

I wish to thank the staff of the Hawaii Division of Fish and Game who collected the fish-catch reports that form the basis of this study. Vernon E. Brock and Tamotsu Shimizu made their data available for study. Additional information was received from Saul Price of the U.S. Weather Bureau who furnished the data on small craft warnings. Peter Wilson of Hawaiian Tuna Packers, Ltd., was instrumental in obtaining the logbooks from two fishing sampans; and Dr. Robert Riffenburgh suggested certain useful statistical procedures.

UTILIZATION OF DATA

The fish-catch reports (fig. 2), completed by the fishermen, were used in this study. Items in these reports are treated as follows:

Time of catch.—The interval from the beginning of 1952 through 1953 was divided into biweekly periods (table 1). Catch reports were grouped by periods according to date of landing.

TABLE 1.—*Biweekly periods in 1952 and 1953*

Period	1952	1953
1	Jan. 1–12	Dec. 28–Jan. 10.
2	Jan. 13–26	Jan. 11–24.
3	Jan. 27–Feb. 9	Jan. 25–Feb. 7.
4	Feb. 10–23	Feb. 8–21.
5	Feb. 24–Mar. 8	Feb. 22–Mar. 7
6	Mar. 9–22	Mar. 8–21.
7	Mar. 23–April 5	Mar. 22–April 4.
8	April 6–19	April 5–18.
9	April 20–May 3	April 19–May 2.
10	May 4–17	May 3–16.
11	May 18–31	May 17–30.
12	June 1–14	May 31–June 13.
13	June 15–28	June 14–27.
14	June 29–July 12	June 28–July 11.
15	July 13–26	July 12–25.
16	July 27–Aug. 9	July 26–Aug. 8.
17	Aug. 10–23	Aug. 9–22.
18	Aug. 24–Sept. 6	Aug. 23–Sept. 5.
19	Sept. 7–20	Sept. 6–19.
20	Sept. 21–Oct. 4	Sept. 20–Oct. 3.
21	Oct. 5–18	Oct. 4–17.
22	Oct. 19–Nov. 1	Oct. 18–31.
23	Nov. 2–15	Nov. 1–14.
24	Nov. 16–29	Nov. 15–28.
25	Nov. 30–Dec. 13	Nov. 29–Dec. 12.
26	Dec. 14–27	Dec. 13–26.

Area of catch.—The catch reports were sorted and reported according to statistical area (fig. 3). For reasons discussed under Sources of Error, the statistical areas have been summarized in terms of zones and regions (fig. 4).

Pounds caught.—This figure was used exactly as recorded in the catch reports.

Average size of skipjack caught.—The total weight was divided by the estimated number caught to arrive at the average weight per fish in the catch. Catches were then classified according to the following categories: (1) small fish (ave age weight 10 pounds or less), (2) large fish (ave age weight greater than 10 pounds), or (3) catch for which no size estimate was possible, becau the number of fish caught was omitted from t report.

Estimate of total number of skipjack caught each size group.—A simple proportion, utilizi the known weights and numbers, was used to es mate the numbers of small and large skipjack the total catch. For example, if the summary data from the fish-catch reports for a particul region and period yields the following inform tion:

Weight and number of fish	Small skipjack	Large skipjack	No size data	Tota
Pounds	30,000	50,000	40,000	120,
Number	6,000	2,500	(1)	(1)

[1] Unknown.

then, the estimated total number of small skipja caught is $\frac{(6{,}000)\cdot(120{,}000)}{80{,}000}=9{,}000$, and the es mated total number of large skipjack caught $\frac{(2{,}500)\cdot(120{,}000)}{80{,}000}=3{,}750$.

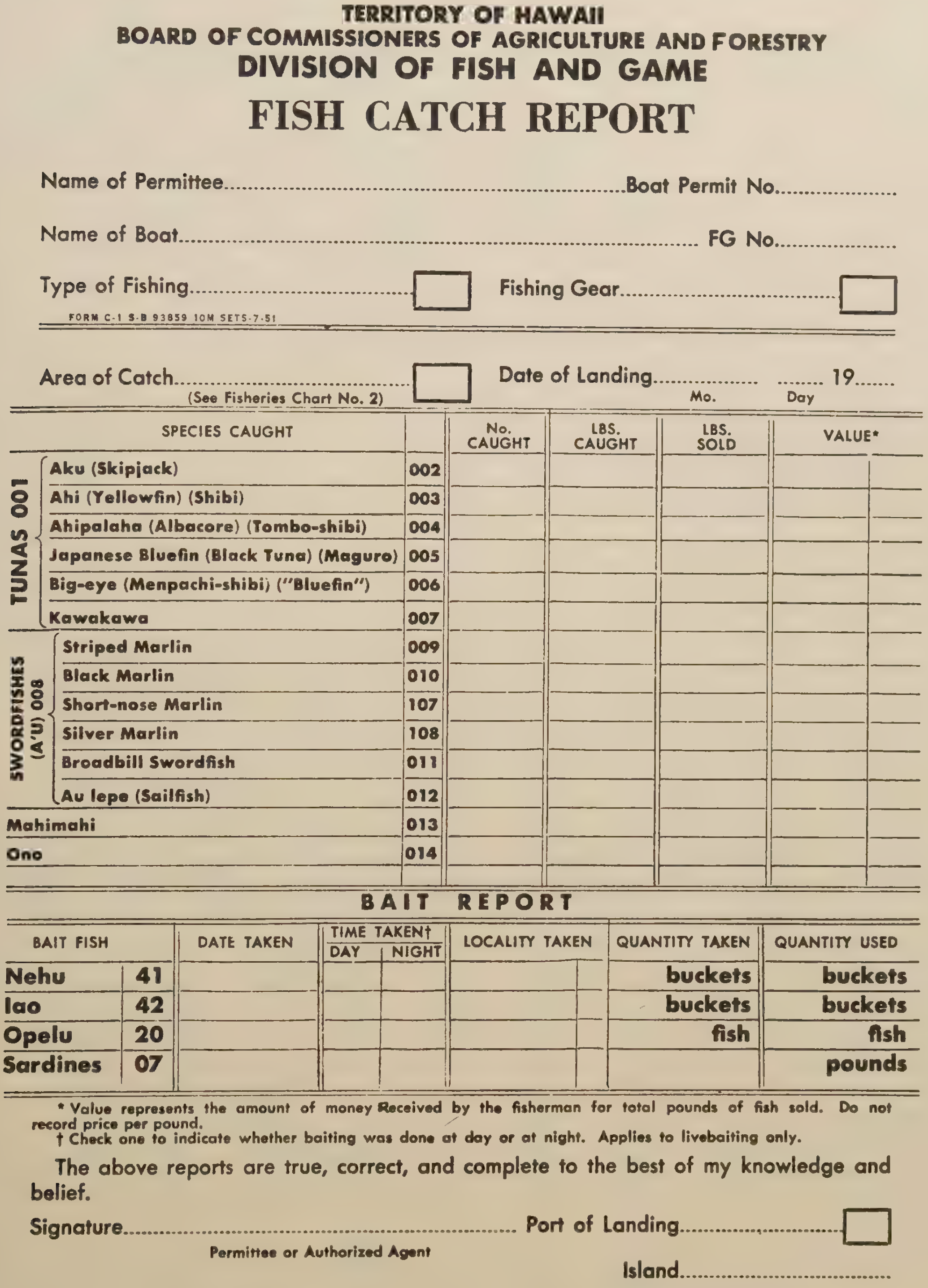
Unusable fish-catch reports.—A small numb of reports was set aside and not used, except accumulate gross totals of pounds caught. If report fell into one or more of the following ca gories, it was classified as unusable: (*a*) no st tistical area was given on catch report, or ar number given did not appear on Division of Fi and Game Chart (fig. 3); (*b*) several statistic area numbers were given so that assignment of t catch to any single zone or region was impossibl (*c*) several trips were apparently grouped on o catch report so that estimates of fishing effc would be erroneous.

All other reports were considered usable.

CHOICE OF UNIT OF FISHING EFFORT

The fish-catch report gives no direct inform tion on the amount of effort. There are no data indicate the number of fishermen making t catch, the time in terms of scouting and fishing, t number of unreported trips with no catch, or ar of the other factors which might be pertinen The fish-catch reports provide, insofar as the d termination of effort is concerned, a listing dates on which fish were unloaded from the vessel. It is from this list, and other data, that fishing effort was estimated.

Each usable catch report was assumed to describe the results of a single trip of the vessel. Each boat has an official number-of-crew, which is reported to the U.S. Customs (Yamashita, 1958, table A–1). This figure, a constant for each vessel, was assigned as a weight to each usable catch report to represent the amount of effort expended in



TERRITORY OF HAWAII
BOARD OF COMMISSIONERS OF AGRICULTURE AND FORESTRY
DIVISION OF FISH AND GAME
FISH CATCH REPORT

Name of Permittee...Boat Permit No....................

Name of Boat.. FG No....................

Type of Fishing.................................☐ Fishing Gear.................................☐

FORM C-1 S-B 93859 10M SETS-7-51

Area of Catch.................................☐ Date of Landing.................. .... 19.......
(See Fisheries Chart No. 2) Mo. Day

SPECIES CAUGHT			No. CAUGHT	LBS. CAUGHT	LBS. SOLD	VALUE*
TUNAS 001	Aku (Skipjack)	002				
	Ahi (Yellowfin) (Shibi)	003				
	Ahipalaha (Albacore) (Tombo-shibi)	004				
	Japanese Bluefin (Black Tuna) (Maguro)	005				
	Big-eye (Menpachi-shibi) ("Bluefin")	006				
	Kawakawa	007				
SWORDFISHES (A'U) 008	Striped Marlin	009				
	Black Marlin	010				
	Short-nose Marlin	107				
	Silver Marlin	108				
	Broadbill Swordfish	011				
	Au lepe (Sailfish)	012				
Mahimahi		013				
Ono		014				

BAIT REPORT

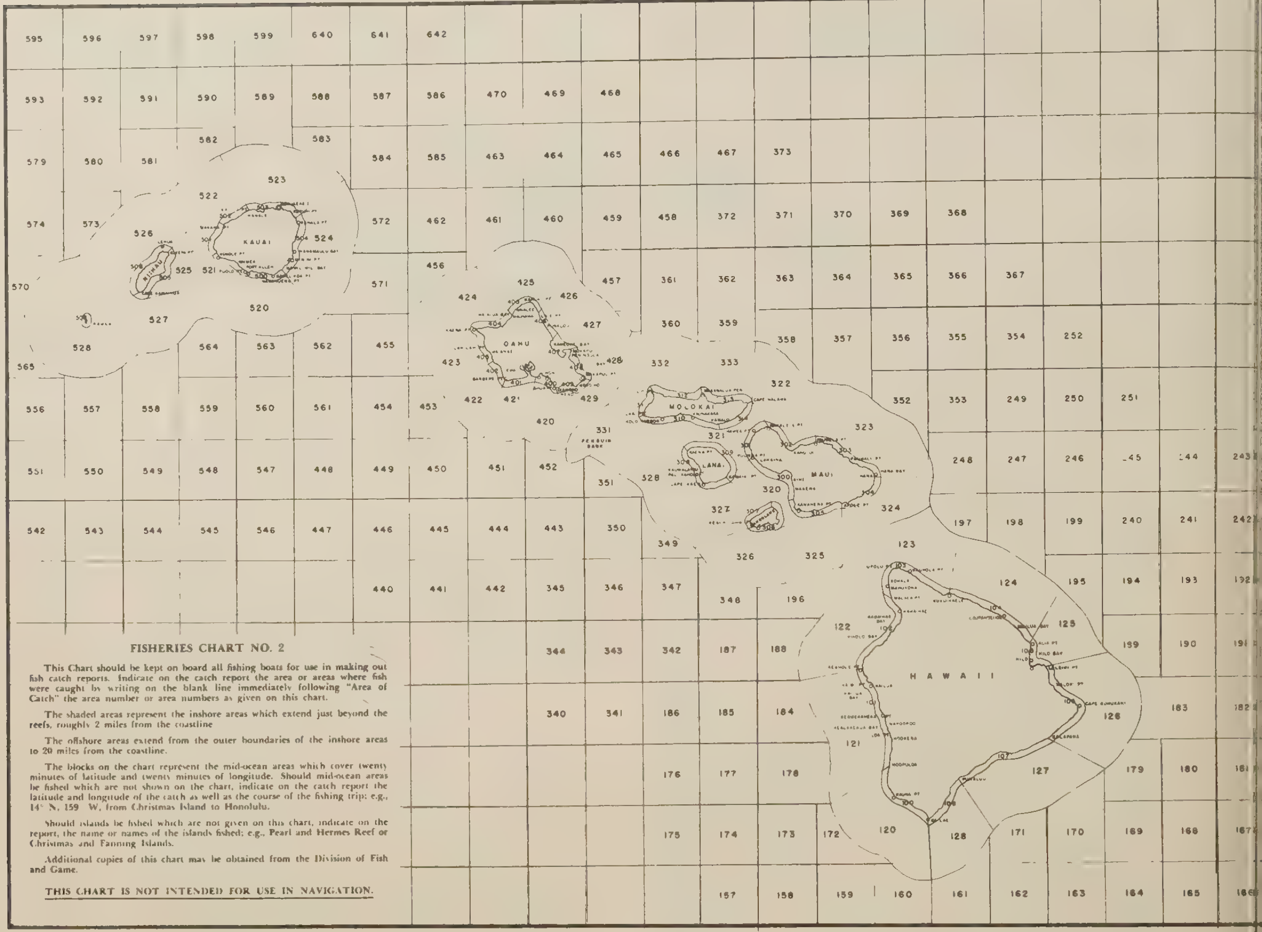
BAIT FISH		DATE TAKEN	TIME TAKEN† DAY	TIME TAKEN† NIGHT	LOCALITY TAKEN	QUANTITY TAKEN	QUANTITY USED
Nehu	41					buckets	buckets
Iao	42					buckets	buckets
Opelu	20					fish	fish
Sardines	07						pounds

* Value represents the amount of money Received by the fisherman for total pounds of fish sold. Do not record price per pound.
† Check one to indicate whether baiting was done at day or at night. Applies to livebaiting only.

The above reports are true, correct, and complete to the best of my knowledge and belief.

Signature.. Port of Landing..............................☐
Permittee or Authorized Agent
Island......................................

FIGURE 2.—Hawaii Division of Fish and Game, Fish Catch Report (1950–54).


595 596 597 598 599 640 641 642
593 592 591 590 589 588 587 586 470 469 468
582 583
579 580 581 584 585 463 464 465 466 467 373
523
522
574 573 526 KAUAI 524 572 462 461 460 459 458 372 371 370 369 368
NIIHAU 525 521 570 571 456 425 426 424 457 361 362 363 364 365 366 367
520 527 OAHU 427 360 359
528 564 563 562 455 423 428 332 333 358 357 356 355 354 252
565 556 557 558 559 560 561 454 453 422 421 429 MOLOKAI 322 352 353 249 250 251
420 331 PENGUIN BANK 321 323
551 550 549 548 547 448 449 450 451 452 LANAI 351 328 MAUI 320 248 247 246 245 244
542 543 544 545 546 447 446 445 444 443 350 327 324 197 198 199 240 241
349 326 325 123
440 441 442 345 346 347 348 196 124 195 194 193
122 125
344 343 342 187 188 HAWAII 189 190
340 341 186 185 184 126 183
121
176 177 178 127 179 180
175 174 173 172 120 128 171 170 169 168
157 158 159 160 161 162 163 164 165

FISHERIES CHART NO. 2

This Chart should be kept on board all fishing boats for use in making out fish catch reports. Indicate on the catch report the area or areas where fish were caught by writing on the blank line immediately following "Area of Catch" the area number or area numbers as given on this chart.

The shaded areas represent the inshore areas which extend just beyond the reefs, roughly 2 miles from the coastline

The offshore areas extend from the outer boundaries of the inshore areas to 20 miles from the coastline.

The blocks on the chart represent the mid-ocean areas which cover twenty minutes of latitude and twenty minutes of longitude. Should mid-ocean areas be fished which are not shown on the chart, indicate on the catch report the latitude and longitude of the catch as well as the course of the fishing trip: e.g., 14° N, 159 W, from Christmas Island to Honolulu.

Should islands be fished which are not given on this chart, indicate on the report, the name or names of the islands fished; e.g., Pearl and Hermes Reef or Christmas and Fanning Islands.

Additional copies of this chart may be obtained from the Division of Fish and Game.

THIS CHART IS NOT INTENDED FOR USE IN NAVIGATION.

FIGURE 3.—Hawaii Division of Fish and Game, Fisheries Chart No. 2, Statistical Areas.

TABLE 2.—*Fishing effort in 1952 and 1953 for two Honolulu-based skipjack boats*

1	2	3	4	5	6	7	8	9	10	11
Boat and period	Number biweekly periods with fishing	Number trips	Number productive trips	Number non-productive trips	Percent non-productive trips	Average number trips per biweekly period	Number days fishing (includes scouting)	Average number days fishing per biweekly period	Average number trips per days fishing	Averag numbe producti trips p days fish
BOAT *A* (*1952*)										
Jan. 1–May 31; Oct. 5–Dec. 27	9	42	37	5	12	4.7	51	5.7	0.82	0
June 1–Oct. 4	9	61	56	5	8	6.8	66	7.3	.92	
Jan. 1–Dec. 27, 1952	18	103	93	10	10	5.7	117	6.5	.88	
BOAT *A* (*1953*)										
Dec. 28, 1952–May 30, Oct. 4–Dec. 26	15	82	74	8	10	5.5	85	5.7	.96	
May 31–Oct. 3	9	58	55	3	5	6.4	59	6.6	.98	
Dec. 28, 1952–Dec. 26, 1953	24	140	129	11	8	5.8	144	6.0	.97	
BOAT *B* (*1952*)										
Jan. 1–May 31; Oct. 5–Dec. 27	11	29	22	7	24	2.6	55	5.0	.53	
June 1–Oct. 4	9	33	31	2	6	3.7	55	6.1	.60	
Jan. 1–Dec. 27, 1952	20	62	53	9	14	3.1	110	5.5	.56	
BOAT *B* (*1953*)										
Dec. 28–May 30; Oct. 4–Dec. 26	16	69	60	9	13	4.3	91	5.7	.76	
May 31–Oct. 3	9	50	47	3	6	5.6	65	7.2	.77	
Dec. 28, 1952–Dec. 26, 1953	25	119	107	12	10	4.8	156	6.2	.76	

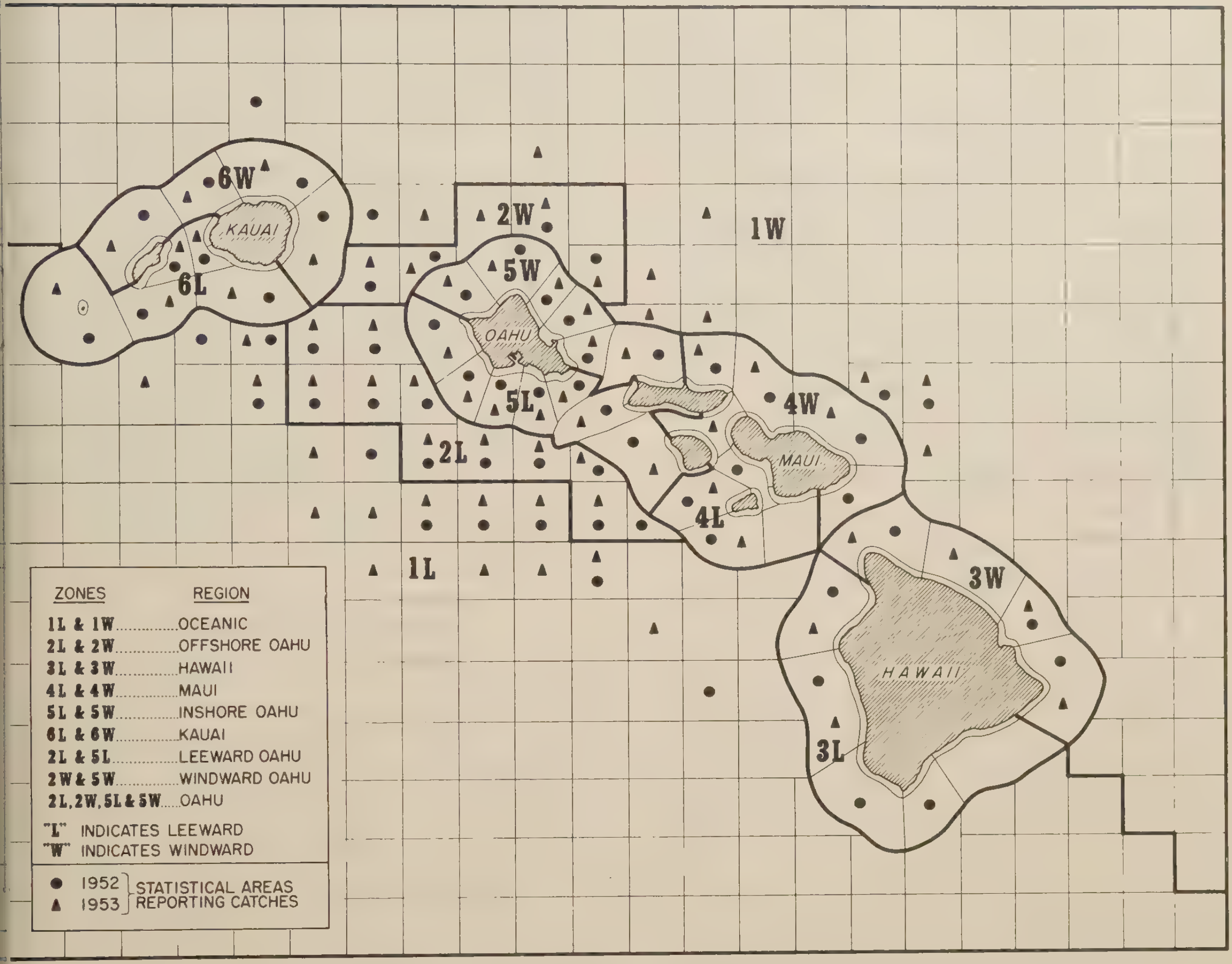

6W
KAUAI
6L
2W
1W
5W
OAHU
5L
2L
4W
MAUI
4L
1L
3W
HAWAII
3L
ZONES REGION
1L & 1W ....OCEANIC
2L & 2W ....OFFSHORE OAHU
3L & 3W ....HAWAII
4L & 4W ....MAUI
5L & 5W ....INSHORE OAHU
6L & 6W ....KAUAI
2L & 5L ....LEEWARD OAHU
2W & 5W ....WINDWARD OAHU
2L, 2W, 5L & 5W .....OAHU
"L" INDICATES LEEWARD
"W" INDICATES WINDWARD
● 1952 } STATISTICAL AREAS
▲ 1953 } REPORTING CATCHES

Figure 4.—Hawaii skipjack fishery fishing zones and regions and the extent of fishing in 1952 and 1953.

making the catch. The number of fishermen is used as a factor in the computation of fishing effort because it seems reasonable that in pole-and-line fishing the efficiency of a vessel is more or less directly related to the number of men hooking fish. No adjustments were made for differences in trip time or for deviations from the official number of fishermen. Inasmuch as a fish-catch report is required only if fish are caught, the unit of effort employed in this study is the productive fisherman-trip. Thus, if a vessel with a registered crew of 10 men reported a catch of 20,000 pounds, the effort is considered to be 10 units and the catch per unit of effort is 2,000 pounds. If two or more catch reports were combined, the sum of the catches was divided by the sum of the effort to obtain the catch per unit of effort.

To gain some knowledge of the reliability of the productive trip as a factor in the unit of effort, the logbooks of two Honolulu-based skipjack fishing sampans were analyzed to determine the ratio of productive trips to the actual number of days spent fishing; i.e., the time spent in scouting for and catching skipjack. The results of this analysis appear in table 2. Boat *A* is typical of the fleet as a whole in that it makes frequent trips of seldom more than a single day. Boat *B*, on the other hand, is probably the most atypical in the fleet since it ventures far afield and may remain at sea for as many as 4 days, especially when skipjack are relatively scarce. The differences between the two boats are apparent in the number of trips per biweekly period (col. 7) and the number of trips per day's fishing (col. 10).

Each year is divided into the more productive and less productive parts; for convenience these are called summer and winter, respectively (rows 1 and 2 for each boat and year). The number of trips per biweekly period (col. 7) and number of day's fishing per biweekly period (col. 9) are greater during summer, but the ratio of trips to day's fishing (col. 10) is not markedly different in the two seasons, although trips are somewhat longer in winter.

Nonproductive trips (col. 5) occur with greater frequency (col. 6) in winter than in summer, and there is a tendency for the number of productive trips per day's fishing to be greater in summer. Differences in the number of productive trips per day's fishing are also apparent between years, as in 1953 there were generally more productive trips per day's fishing than in 1952.

To summarize the performances of the two boats, it appears that the ratio of productive trips to the number of day's fishing is greater during times of good fishing and smaller during times of poor fishing. Since trips are shorter when the fishing is good and there are also fewer nonproductive trips, the actual effort in terms of day's fishing will usually be underestimated during the periods of poor fishing as compared with periods of good fishing.

Variations from the official number of crew will also affect the accuracy of the estimate of fishing effort. The official number is a maximum and variations will usually mean that fewer than the official number are aboard. In the Hawaiian skipjack fleet, boats ordinarily carry the maximum number of crew during the summer season, after which some men leave to find other employment. In this study, since the official (maximum) number of crew has been used throughout the year as a weight for the individual trip, the "fisherman" factor in the productive fisherman-trip is probably overestimated during the times of poor fishing.

Thus, the biases in the productive fisherman-trip between times of good and poor fishing tend to cancel each other because during the winter season and years of generally poor fishing, longer trips and the increased frequency of nonproductive trips cause an underestimation of the actual time spent fishing while, at the same time, the actual number of fishermen on the boat is likely to be fewer than the official number. The converse will hold true during the summer season and in years when good fishing attracts the maximum number of fishermen to the fleet.

Information is not available to permit the examination of the actual variations in the number of fishermen and the extent to which they offset the bias introduced by nonproductive trips, but if boat *A* is assumed to represent the average situation, the number of productive trips per day's fishing (col. 11) appears to be about 10 percent greater in summer than in winter. Since the crew of the average skipjack boat is about 10 men, the absence of one of these men on the average during the winter season represents a 10-percent overestimation of the number of fishermen. Thus, the absence of one fisherman per boat during the winter season would be sufficient to equalize the bias in the productive trip factor introduced during the winter season.

SOURCES OF ERROR

Unreported catches or forms containing incomplete or inaccurate information are an obvious source of error. Yamashita (1958, p. 258) estimates that the reported portion of the 1952 catch included 94 percent of the pounds, but only 88 percent of the trips, indicating a bias in favor of the reporting of large catches. Since small catches are most likely to occur in the slack part of the year, there may be a tendency for an estimate of the fishing effort, which is a function of the number of trips, to be correspondingly reduced.

Inaccurate information is difficult to detect without data from other sources with which to compare the catch records. On the basis of interview records, Yamashita (1958, p. 258) estimates that only 45 percent of the statistical areas indicated in the 1952 catch reports were reasonably accurate. By means of broad geographical divisions to summarize the data (fig. 4), it is assumed that the effects of such erroneous information will be minimized.

ERROR IN DETERMINATION OF FISH SIZE

Dividing the total weight caught by the estimated number as indicated in the catch report, yields the average size of fish caught, but provides no indication of the range or variability of sizes. Since the entire catch is assigned to either the small or large category on the basis of the average weight per fish, a certain amount of error will result from mixed catches of small and large fish; this error should distribute itself more or less randomly, however, so that neither size group is consistently favored.

ERROR IN ESTIMATION OF FISHING EFFORT

There is no way to determine from the catch records the actual effort, i.e., the fisherman-days whether productive or not, put forth on a skipjack boat. In this study only positive fishing results (catch reports) are available, and the productive fisherman-trip is of necessity used in lieu of the fisherman-day. Sources of error in the productive fisherman-trip have been discussed in the section, Choice of the Unit of Fishing Effort, and on the basis of the performance of two skipjack boats for which logbooks are available, it appears to be a reasonable substitute.

OTHER SOURCES OF ERROR

The weight of the catch of skipjack taken in the Hawaiian live-bait fishery is affected by complex factors which present sources of error that are difficult to estimate. Among these factors are variations in bait supply, response of skipjack to chum, behavior and number of birds in the flocks which serve to locate schools, the size and behavior of the skipjack schools, selection by the fishermen, and probably several others.

Yamashita (1958, p. 270) has discussed the problem of ascertaining the influence of variations in bait supply on the skipjack catch in terms of annual production and suggests that in certain years, when skipjack have been plentiful, the availability of bait may be a limiting factor in the fishery. Royce and Otsu (1955) have investigated many aspects of behavior of skipjack schools and birds; Yuen (1959) has studied the response of skipjack to live bait.

In the present study no attempt has been made to evaluate the sources of error introduced by the factors considered above. Information available is not adequate to discern which of these may be important at any particular time. It seems reasonable that most of these factors act relatively independent of one another so that over a period of time their combined effects should not introduce bias. However, it is just as plausible that at certain times several of these elements may act in unison resulting in considerable deviation from the normal state. The investigation of the role of these factors in the fishery awaits a more sophisticated study than is attempted here or is possible with the present sources of information.

CONCLUSIONS ON SOURCES OF ERROR

None of the sources of error appears to be so extensive as to destroy the usefulness of the catch report as the basis for a study of distribution and abundance. Some of the sources of error tend to reduce the bias introduced by others. With respect to time, geography, and size, the categories employed in this study have deliberately been made broad. Were the study concerned with only a few vessels, very short time periods, or several size groups, the probability of error would be increased, but as only the most general of categories are used, the influence of error on the results should be slight.

RESULTS AND DISCUSSION

There are small discrepancies between the official total catches for 1952 and 1953 as listed by Yamashita (1958, table 2) and the totals obtained in the present study (table 3). These differences amount to 1 percent and are probably the result of catch reports, which were turned in too late to be included in official summaries and to records lost or misplaced during the interval of storage. The proportion of unusable data in 1953 was greater than in 1952 (table 4), largely because of the poor

TABLE 3.—*Comparative data from 2 studies of the Hawaiian skipjack catch for 1952 and 1953*

Year	Pounds skipjack caught		Difference	Percent difference
	Yamashita [1]	Shippen [2]		
1952	7, 291, 851	7, 390, 882	99, 031	1. 3
1953	12, 059, 406	11, 928, 965	−130, 441	−1. 1

[1] Source: Yamashita (1958, table 2).
[2] Figures adjusted to correspond with calendar year.

TABLE 4.—*Usability of 1952 and 1953 catch report data*

	1952		1953	
	Pounds	Percent	Pounds	Percent
Usable	7, 270, 990	98. 6	11, 345, 013	95. 0
Unusable	105, 453	1. 4	598, 391	5. 0
Total	7, 376, 443	100. 0	11, 943, 404	100. 0

reports from the master of one sampan who consistently summarized his catches by weeks throughout much of the year.

GEOGRAPHICAL DISTRIBUTION OF 1952 AND 1953 CATCHES

Despite the large differences in total landings in 1952 and 1953, the geographical distribution of catch and effort (table 5, fig. 5) is much the same. In both years the leeward Oahu and Hawaii regions furnished approximately 50 and 16 percent of the total catch, respectively, and the oceanic region and Maui were relatively unimportant with less than 8 percent in the aggregate. The combined windward Oahu and Kauai regions contributed about 25 percent of the total catch in each year, but in 1953 a much larger proportion of this came from windward Oahu.

Within the vicinity of Oahu, the distribution of effort appears to be related to the distance from the home port; the amount of effort expended in the zones decreases as their distance from Honolulu increases. This is probably because of the fragile nature of the nehu (*Stolephorus purpureus*), the most important bait species.

CATCH PER UNIT OF EFFORT IN THE HAWAII SKIPJACK FISHERY

If the regions of the fishery from Hawaii in the southeast to Kauai in the northwest are arranged in sequential order (fig. 6), there is some suggestion of an increasing catch per unit-of-effort in the direction of Kauai, but the inequities in the distribution of effort and certain known differences in the local fisheries make it doubtful that the apparent trend is of biological significance. The Hilo (Hawaii) fishermen usually make short trips and land each day's catch on the day it was made,

TABLE 5.—*Geographical distribution of the 1952 and 1953 usable catch data*

[See fig. 4 for location of zones; C/E=catch/effort]

Regions and zones	1952					1953				
	Catch		Effort		C/E	Catch		Effort		C/E
	Pounds	Percent	Units	Percent		Pounds	Percent	Units	Percent	
Oceanic:										
1L	183, 729	2. 5	244	1. 2	753	274, 358	2. 4	439	1. 7	62
1W	128, 458	1. 8	348	1. 8	369	191, 531	1. 7	236	0. 9	81
Total	312, 187	4. 3	592	3. 0	527	465, 889	4. 1	675	2. 6	69
Hawaii:										
3L	252, 659	3. 5	1, 073	5. 4	235	485, 317	4. 3	1, 572	6. 2	30
3W	881, 673	12. 1	2, 869	14. 6	307	1, 288, 967	11. 4	3, 676	14. 4	35
Total	1, 134, 332	15. 6	3, 942	20. 0	288	1, 774, 284	15. 6	5, 248	20. 6	33
Maui:										
4L	115, 113	1. 6	119	0. 6	967	25, 257	0. 2	62	0. 2	40
4W	139, 939	1. 9	463	2. 4	302	179, 291	1. 6	452	1. 8	39
Total	255, 052	3. 5	582	3. 0	438	204, 548	1. 8	514	2. 0	39
Inshore Oahu:*										
5L	2, 259, 734	31. 1	7, 350	37. 3	307	3, 365, 538	29. 7	9, 116	35. 7	36
5W	719, 780	9. 9	1, 952	9. 9	369	1, 742, 242	15. 3	3, 266	12. 8	53
Total	2, 979, 514	41. 0	9, 302	47. 2	320	5, 107, 780	45. 0	12, 382	48. 5	41
Offshore Oahu:*										
2L	1, 486, 181	20. 4	3, 519	17. 9	422	2, 656, 150	23. 4	5, 022	19. 7	52
2W	157, 854	2. 2	361	1. 8	437	415, 346	3. 7	674	2. 6	61
Total	1, 644, 035	22. 6	3, 880	19. 7	424	3, 071, 496	27. 1	5, 696	22. 3	53
Oahu region subtotals:*										
L	3, 745, 915	51. 5	10, 869	55. 2	345	6, 077, 707	53. 6	14, 242	55. 8	42
W	877, 634	12. 1	2, 313	11. 7	379	2, 212, 112	19. 5	3, 990	15. 6	55
Region total	4, 623, 549	63. 6	13, 182	66. 9	351	8, 289, 819	73. 1	18, 232	71. 5	45
Kauai:										
6L	284, 845	3. 9	560	2. 8	509	217, 722	1. 9	373	1. 5	58
6W	661, 025	9. 1	844	4. 3	783	392, 751	3. 5	462	1. 8	85
Total	945, 870	13. 0	1, 404	7. 1	674	610, 473	5. 4	835	3. 3	73
Grand total	7, 270, 990	100. 0	19, 702	100. 0	369	11, 345, 013	100. 0	25, 504	100. 0	44

*The Oahu region includes inshore and offshore Oahu, 2L, 5L, 2W, and 5W. For 1953, a few additional catches were made across zone boundaries withi the Oahu region.

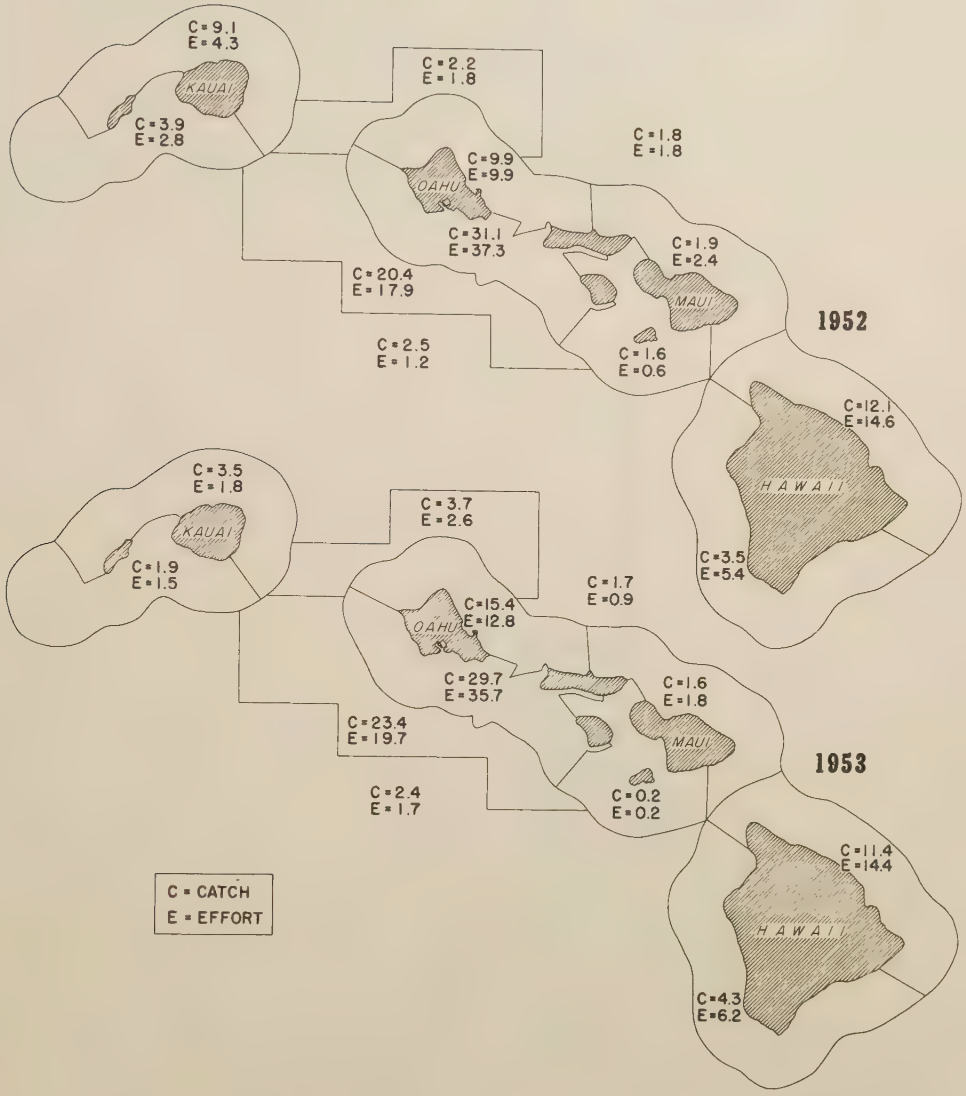

C=9.1
E=4.3
KAUAI
C=3.9
E=2.8
C=2.2
E=1.8
C=1.8
E=1.8
C=9.9
E=9.9
OAHU
C=31.1
E=37.3
C=1.9
E=2.4
MAUI
C=20.4
E=17.9
1952
C=2.5
E=1.2
C=1.6
E=0.6
C=12.1
E=14.6
HAWAII
C=3.5
E=5.4
C=3.5
E=1.8
KAUAI
C=1.9
E=1.5
C=3.7
E=2.6
C=1.7
E=0.9
C=15.4
E=12.8
OAHU
C=29.7
E=35.7
C=1.6
E=1.8
MAUI
C=23.4
E=19.7
1953
C=2.4
E=1.7
C=0.2
E=0.2
C=11.4
E=14.4
HAWAII
C=4.3
E=6.2
C = CATCH
E = EFFORT

FIGURE 5.—Geographical distribution of catch and effort in the Hawaiian skipjack fishery, 1952 and 1953.

whereas the trips by Honolulu-based fishermen to the vicinity of Kauai are longer than a single day; therefore, the differences in time-of-trip between the two areas are probably significant.

Similarly, catch per unit of effort tends to increase with increasing distance from shore (fig. 7). Only a fraction of the total effort was expended in the oceanic region as compared with the effort inshore, and a few good catches of large fish may have produced an index far out of proportion to the actual apparent abundance. Royce and Otsu (1955, p. 18), however, report sighting more tuna schools per day's scouting beyond 19 miles from shore than were seen within 19 miles of shore.

SIZE OF SKIPJACK AND POUNDS CAUGHT PER UNIT OF EFFORT

There is a positive correlation (fig. 8) between the average size of skipjack caught in zones of the fishery during the year (table 6) and corresponding catch per unit of effort (table 5). Zones with less than 5 percent of the total annual effort are not included in the analysis because they are unlikely to represent fishing conditions throughout the year. This correlation appears to substantiate the observation that the larger skipjack usually can be caught more efficiently than the smaller, up to the size at which individuals must be gaffed in landing and the efficiency drops.

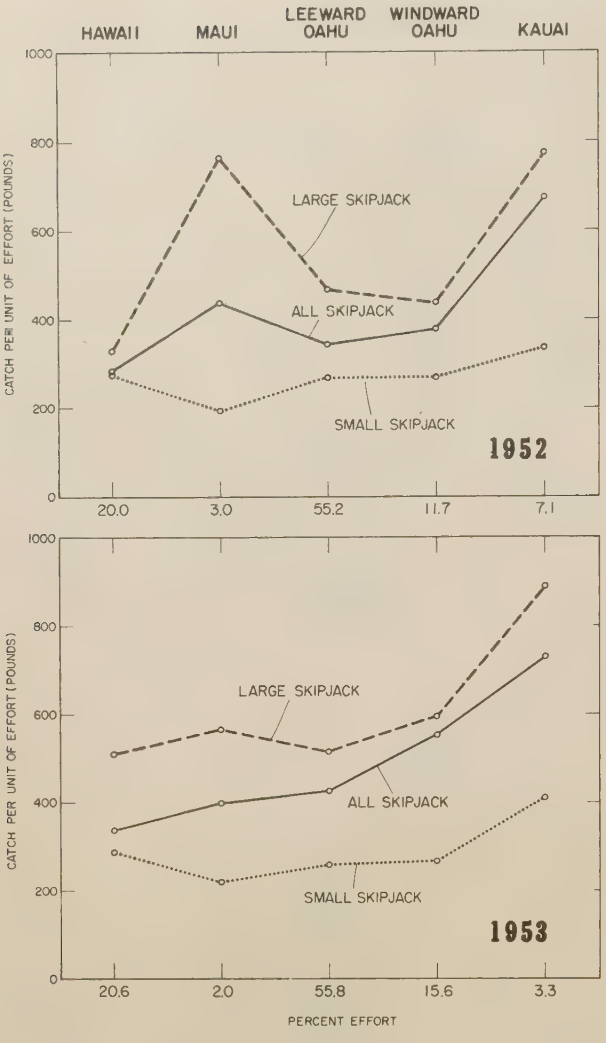


Figure 6.—Pounds caught per unit of effort by island regions.

Table 6.—*Average weight of skipjack caught in each zone of the fishery*

Zone	1952	1953	Zone	1952	1953
	Average weight (pounds)	Average weight (pounds)		Average weight (pounds)	Average weight (pounds)
1L	15.5	18.2	4L	14.5	12.1
1W	7.9	14.7	4W	11.9	13.0
2L	*9.0	*13.9	5L	*8.2	*11.2
2W	17.2	15.9	5W	*9.2	*12.8
3L	*4.8	*7.7	6L	6.7	11.5
3W	*4.8	*7.5	6W	12.8	8.1

*Indicates zones receiving more than 5 percent of the total fishing effort during the year.

Each year the small fish are caught in Hawaii (zones 3L and 3W); the larger fish are from inshore windward Oahu (5W), and offshore leeward Oahu (2L). The association of small fish with

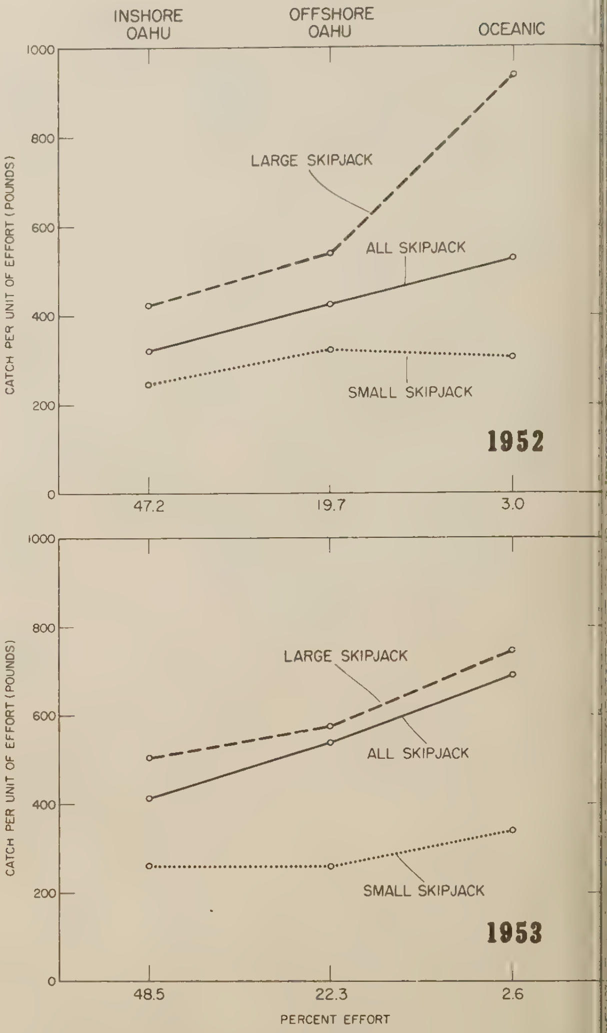


Figure 7.—Pounds caught per unit of effort by distanc from shore.

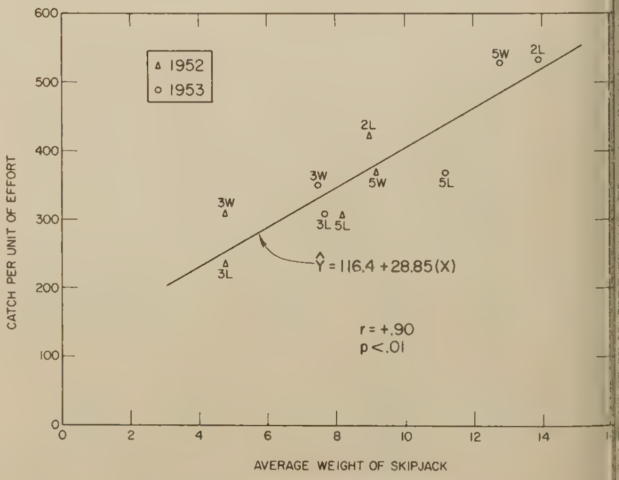


Figure 8.—Regression of catch per unit of effort o average weight of fish caught.

Hawaii may be explained by the nature of the fishery there, which is based largely on semiresident populations of small skipjack. Other populations of small fish are known to occur in inshore areas of leeward Oahu (5L), and these are usually exploited when the large skipjack are in low abundance and produce the intermediate average weight for zone 5L. Zones 5W and 2L are more remote from Honolulu than is 5L, and it seems probable that the fishery in these zones may be biased in favor of periods when large skipjack are available, which could account for the relatively greater average weight per fish in these zones of the fishery.

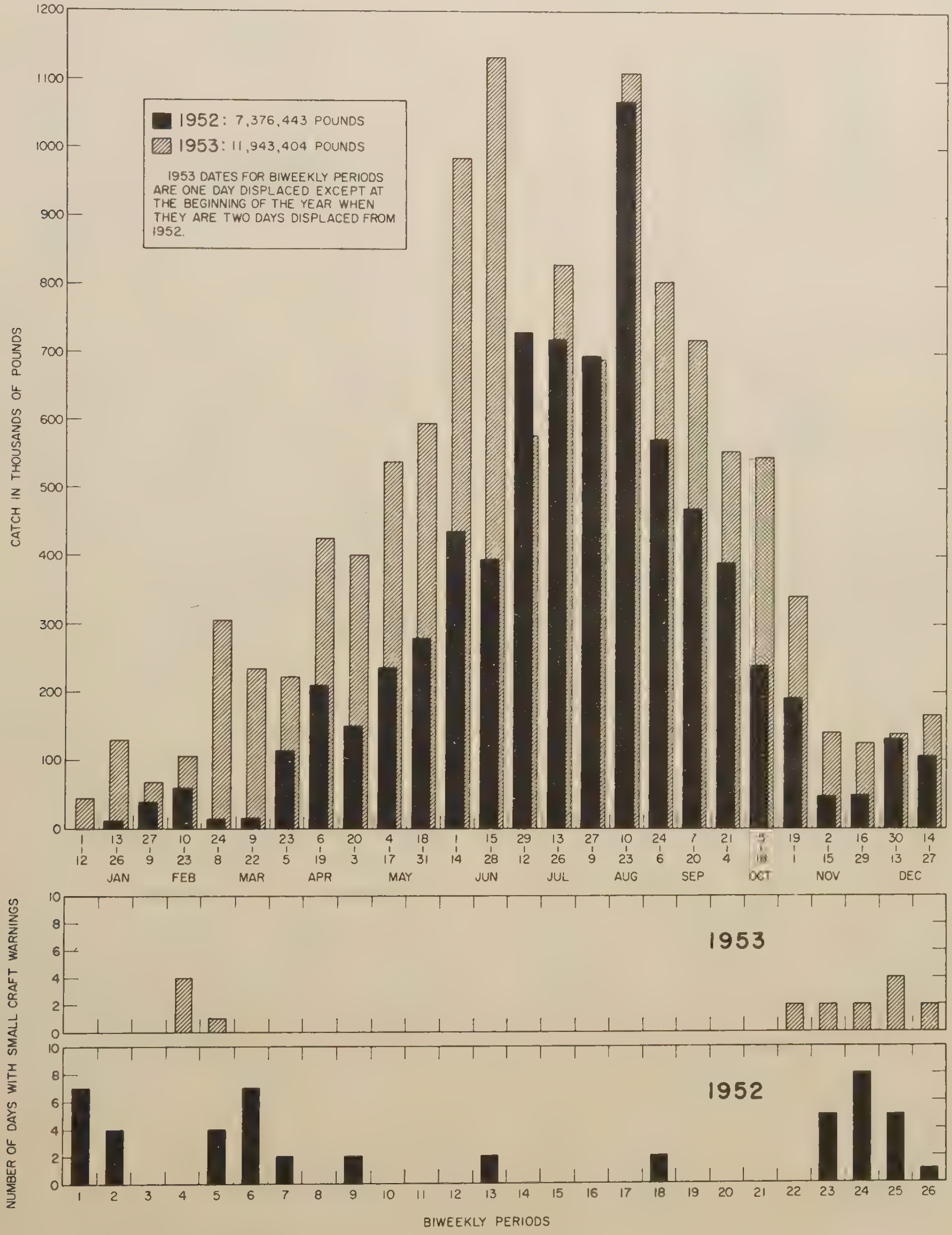


Figure 9.—Catches (pounds) of the Hawaii skipjack fishery, 1952–1953, by biweekly periods. Periods of small craft warnings are shown below.

DISTRIBUTION OF 1952 AND 1953 CATCHES BY BIWEEKLY PERIODS

Catches for the Entire Fishery

Only during July and August (periods 14–17) and briefly in December (period 25) did the 1952 skipjack catches reach the magnitude of the 1953 totals (fig. 9). In particular, the spring of 1953 and, to a lesser extent, the autumn months provided much larger catches than occurred in 1952.

Effects of Small Craft Warnings

There were 49 days with small craft warnings during 1952 and 17 during 1953 (fig. 9), but only 6 of these fell in the interval from April through September in 1952 and none in 1953. The effects of rough weather, therefore, appear to be relatively minor in comparison with the seasonal fluctuation in the availability of skipjack.

The immediate effects of poor weather may be indicated by the relatively small catches made during periods 1, 2, 5, 6, 23, and 24 of 1952, each of which had several days with small craft warnings. Period 25, on the other hand, shows an increase in catch despite 5 days of poor weather.

MOVEMENTS OF SKIPJACK WITHIN THE FISHERY

Local changes in the skipjack catch within the entire range of the fishery may result from changes in the amount of fishing effort or from changes in availability. The latter may include horizontal movement of the fish into or out of a particular area or, within an area, a change in the vertical distribution or behavior such that the catch rate by live bait fishing is affected. The records of the fishery, however, provide no means by which one or the other cause may be determined, and it is therefore assumed for the purposes of this discussion that all changes in the catch are caused by movements of fish from one area to another. Thus, errors, if any, are likely to be on the side of postulating a horizontal movement of fish when there has been a change in vertical distribution, behavior, or fishing effort. This approach seems to be the most reasonable one, because tagging experiments show that individual skipjack travel the length and breadth of the fishery, while knowledge of changes in availability and fishing effort, particularly if nonproductive, remains quite limited.

Large Skipjack

After an interval of low abundance throughou the islands during the early part of 1952, large skipjack (fig. 10) appeared simultaneously in small numbers in leeward Oahu and Kauai in period 8. In period 10 the fish arrived in windward Oahu and Hawaii. This sequence suggests an approach from the west. In period 12, a concentration centered in windward Oahu occurred; it appears to have shifted northward to Kauai by periods 15 and 16. In period 17, however, the catches of large skipjack ceased in Hawaii and began to dwindle in Kauai, but at the same time the largest catches of the year were being made in leeward Oahu. All these changes seem to indicate that the large skipjack had returned to the leeward side of the island chain. The gradually diminishing catches from Kauai and leeward Oahu in periods 18 through 20 indicated the withdrawal of season fish to the westward. After period 20, the numbers of large skipjack in the catch returned to the state of low variable abundance which characterizes the off-season of the fishery.

During the interval from period 25 (1952) until period 4 (1953) the number of large skipjack taken in all regions of the fishery was uniformly low, a condition typical of the winter season. In period 5, however, a sharp increase occurred in the catch of large skipjack in the leeward Oahu region. To judge from the variation in average weights (fig. 12), these fish were 1952-season fish, being somewhat heavier than 1953-season fish which entered the fishery in period 9. These 1952-season fish appeared in the catches during periods 5, 7, 8, and 9 and were the cause of the apparent early beginning of the "season" in 1953 (fig. 9).

In period 9 of 1953, the season fish were present throughout most of the fishery (note the declining average weights in periods 9 and 10, fig. 12) but the large catches in leeward Oahu in periods 10 through 12 suggest that the direction of the approach of the main body of fish was from the leeward. As in the previous year, a peak occurred early in the season in windward Oahu (period 12, 1952; period 13, 1953), and in succeeding periods the fish dispersed southward to leeward Oahu and Hawaii where large catches were made in periods 15–17. Following the excellent catches of period 17, the best of the year, a gradual decrease in catch occurred, and by period 23 the season was over.

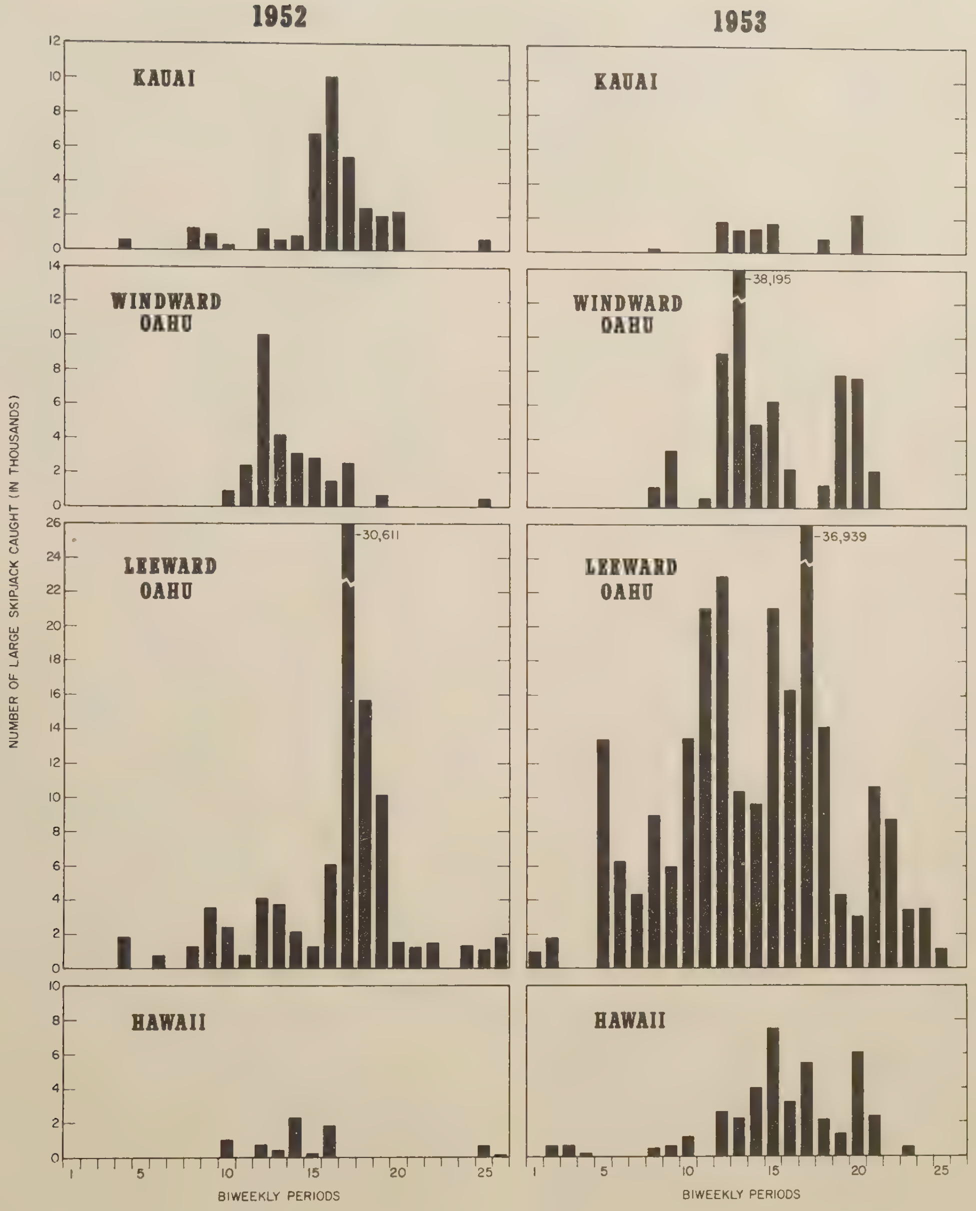


Figure 10.—Number of large skipjack caught (1952–53) ; biweekly periods.

Certain features common to both years are to be noted: (1) the approach of the large fish at the start of the season, apparently from the leeward; (2) the concentrations on the windward and leeward sides of Oahu in June and August, respectively; and (3) the final disappearance of fish to the leeward. Differences in the 2 years are as follows: (1) the appearance in the early part of 1953 (period 5) of large skipjack, and (2) the direction of movement of the season fish between the time of the windward Oahu peak catches (periods 12–13) and the leeward Oahu peak (period 17). In 1952 the fish went northward to Kauai and thus close to the limit of the fishery. In 1953 they returned to leeward Oahu and Hawaii to remain well within the range of the Honolulu and Hilo based vessels.

In general, the movements of large skipjack, as indicated by their occurrence in the commercial catch, do not suggest an orderly migration along the island chain. The reason for this may be in the direction of approach of the migrating schools, which appears to be perpendicular rather than parallel to the barrier formed by the islands. The relative speed with which schools travel, which may reach 15 knots (Royce and Otsu, p. 18), may be such that a period of 2 weeks is too long to discern a migratory pattern within an area as small as that encompassed by the Hawaiian skipjack fishery.

Small Skipjack

Examination of the numbers of small skipjack caught and the corresponding catch per unit-of-effort data revealed no discernible pattern of movement within the fishery. Large skipjack are the prime objective of the fishery and the smaller sizes are usually taken as a second choice. The number of small skipjack in the catch, therefore, tends to be a function of the number of large fish available. The relationships between the numbers of large and small fish in the catch are discussed under the section, Size Composition.

OAHU SKIPJACK FISHERY, 1952 AND 1953

STATISTICAL COMPARISONS

The comparative statistics for 1952 and 1953 in the Oahu region are summarized in table 7. In almost every way, 1953 reflects the greater availability of skipjack than in the previous year, as evidenced by (1) a much larger catch, (2) almost half as much fishing effort, and (3) a larger catch per unit of effort. The number of small skipjack caught (4b) and pounds caught per unit of effort (3b) are not markedly different between years, but the catch of large fish, both in absolute numbers (4a) and on a relative basis (3a), is considerably greater in 1953. Most of the differences between the 2 years can be attributed to the abundance of this size group in the fishery.

Independently of size considerations, the number of fish taken per biweekly period in 1953 was larger than the corresponding number in 1952 (5 and 6). The relative abundance of large and small skipjack in the 2 years is indicated by the number caught per unit of effort (7) which is greater for the small fish in 1952 and for the large fish in 1953. The importance of the abundance of large fish to the success of the fishery may be measured by the comparative number of biweekly periods in the various categories (8).

TABLE 7.—*Comparative statistics for the Oahu fishery, 1952 and 1953*

	1952	1953	1953/1952
1. Total pounds caught	4,623,549	8,715,958	1.89
(Percent of total for skipjack fishery)	(63)	(73)	----------
a. Large skipjack only	2,058,921	6,366,336	3.09
b. Small skipjack only	2,564,628	2,349,622	.92
2. Total productive effort	13,182	19,169	1.45
a. Large skipjack, percent	34	55	----------
b. Small skipjack, percent	66	45	----------
3. Pounds caught per unit of effort, all usable catches	351	455	1.30
a. Large skipjack only	462	533	1.15
b. Small skipjack only	270	261	.97
4. Total number of fish caught	521,500	677,000	1.30
a. Large skipjack only	123,500	330,500	2.67
b. Small skipjack only	398,000	346,500	.87
5. Average number caught per biweekly period	20,577	26,038	1.27
6. Median number of skipjack caught in each year for the 26 biweekly periods	18,044	25,833	1.43
7. Number of fish caught per unit of effort	40	35	.88
a. Large skipjack only	28	31	1.11
b. Small skipjack only	46	40	.87
8. Number of biweekly periods with—			
a. more than 300,000 pounds catch	5	14	2.80
b. more than 800 units fishing effort	5	11	2.20
c. more than 400 pounds catch per unit of effort	5	14	2.80

RELATIONSHIPS BETWEEN CATCH STATISTICS

The population indices derived from the catch reports are the raw catch and the relative catch; i.e., catch per unit of effort. Either index may be in terms of weight or number of fish and may be calculated for the entire catch or for limited categories. Since 1954, however, no information on the number or size of fish in the catch has been included in the catch report, so the only indices which may be considered for recent years in the fishery are the pounds caught and the catch per unit of effort without respect to size categories.

The biweekly statistics for pounds caught, catch per unit of effort, and effort within the Oahu region for 1952 and 1953 are plotted in figure 11. Of particular interest here is the relation between the raw catch and the catch per unit of effort, for if the two show essentially the same variation, there is little or no advantage to be gained in employing catch per unit of effort as the index of apparent abundance.

It is obvious from figure 11 that there is much similarity in the fluctuations of all three indices; each has a seasonal variation on which lesser fluctuations are superimposed. Additionally, there is a secular trend from 1952 to 1953. The catch curve tends to change gradually and peak sharply, while the effort curve changes rapidly at the start and close of the season, with little trend during midyear.

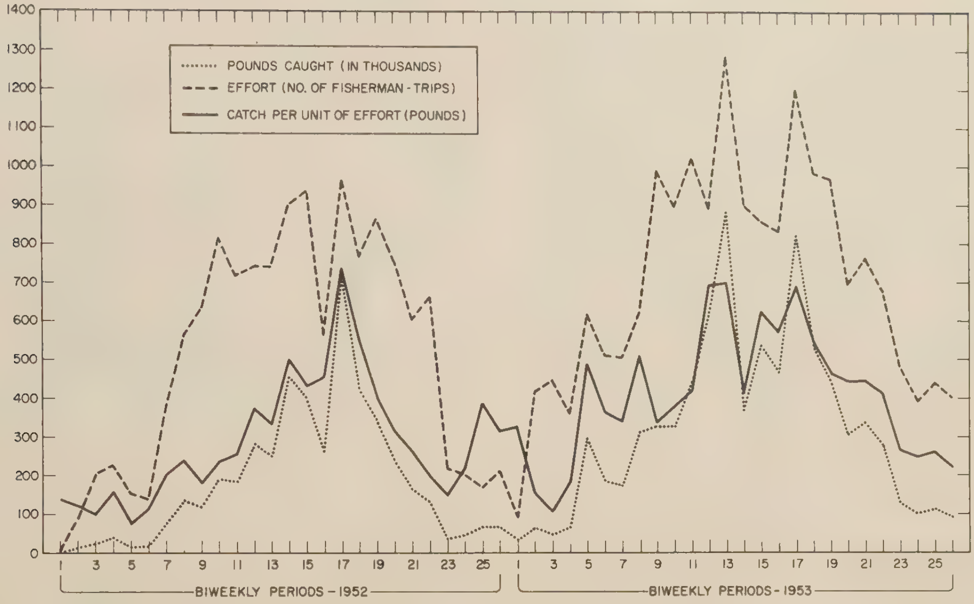


FIGURE 11.—Oahu region catch statistics, 1952 and 1953, biweekly periods.

The results of these tendencies in catch and effort curves on the catch per unit-of-effort curve are as follows: (1) During midyear when effort tends to be constant, the catch per unit of effort will closely follow the fluctuations in catch. (2) During the onset and decline of the season, effort is changing more rapidly than catch and the catch per unit of effort will change at an intermediate rate. Random fluctuations in the catch per unit-of-effort at this time may be somewhat at variance with those in the catch, as occurred in the interval from period 24, 1952, to period 3, 1953.

Correlation analysis between raw catch and catch per unit-of-effort data yields a coefficient of +0.92. It was necessary to use rank correlation methods (Snedecor, 1956, p. 190) because the distribution of catches is skewed toward small catches. In order to determine the amount of agreement between the random fluctuations in the two indices, the first differences were correlated and yielded a coefficient of +0.79. Conventional methods were used here because the first differences are distributed more normally than the original series. The probability that correlation coefficients this large would occur by chance is less than 0.01.

The variate-difference technique (Kendall, vol. II, p. 387–390) was used to obtain an estimate of the variance in the random component of each index compared to the variance of the original series. The values obtained for the random components were 24 percent for the raw-catch series and 18 percent for the catch per unit-of-effort series. Since it exhibits a smaller random component, the catch per unit-of-effort series appears to be somewhat more reliable than the catch as an index of skipjack availability, but only slightly so.

In summary, the raw catch is almost as accurate as the catch per unit of effort in indicating the seasonal variation in skipjack abundance in the Hawaiian fishery. During the middle of the year the raw catch is in good agreement with the random fluctuations in catch per unit of effort, but during the off-season of the fishery, when effort and catch are either declining rapidly or are at a low level, random fluctuations in catch per unit of effort may not vary in agreement with fluctuations in catch. For most purposes, total catch would appear to be as useful an indicator of availability as the catch per unit of effort, especially in problems where the seasonal trend in the fishery is apparent.

USE OF CATCH RECORDS TO DETERMINE POPULATION COMPOSITION

The catch statistics of the Hawaiian fishery are the only continuous source of information which provides a means of assessing the nature of the skipjack population which supports the fishery. Inferences about this population must be made with caution, however, because the fishery is limited geographically to the immediate island area (fig. 4). Furthermore, the catches are also influenced by availability, fishing effort, and selectivity on the part of the fishermen, which may not be constant throughout the year. Brock (1954, p. 100–103) has shown, by means of sex ratios, that the availability of female skipjack is not constant. He suggests that spawning activity may be the crucial element. The cyclical nature of fishing effort has been shown previously (fig. 11), and the fact that the fishermen are selective in the schools they fish is common knowledge. These biases appear to have an annual cycle and between-year comparisons may not be affected by them to the extent of within-year comparisons.

Fluctuations in the Catch of Large Skipjack in the Oahu Region

The growth rate of Hawaiian skipjack has been studied by Brock (1954, pp. 96–97) by means of length frequency distributions. During the summer there are two distinct modes, one at about 45 cm. (4 pounds) and one at about 70 cm. (18 pounds).[1] The mode of large skipjack represents season-fish and presumably a smaller number of the previous year's season-fish. It is this mode that is considered here as large skipjack. The time of year when a mode, which Brock assumes to be a year class, passes through the weight (10 pounds) which separates small and large fish in this study, is apparently winter or early spring. During the period from May to October, it may be assumed with reasonable certainty that the small skipjack are a year younger than the large skipjack.

In 1952 there appears to be little consistency in the average weight for large skipjack (fig. 12), which fluctuates widely from one biweekly period to the next. By contrast, 1953 has an interval from May 3 through October 3 (periods 10–20) with a regularly increasing weight for large fish. The rate of this increase, 0.25 pound per week, is in agreement with Brock's curve for skipjack growth, which yields a linear weight increase of 0.25 pound per week. The coincidence of the season of greatest productivity (as indicated by the number of large fish caught) with the interval of uniform weight increase suggests that in 1953 a single population of season skipjack was available to the fishery, but the erratic fluctuation in the numbers taken indicates that variations in this availability were quite marked.

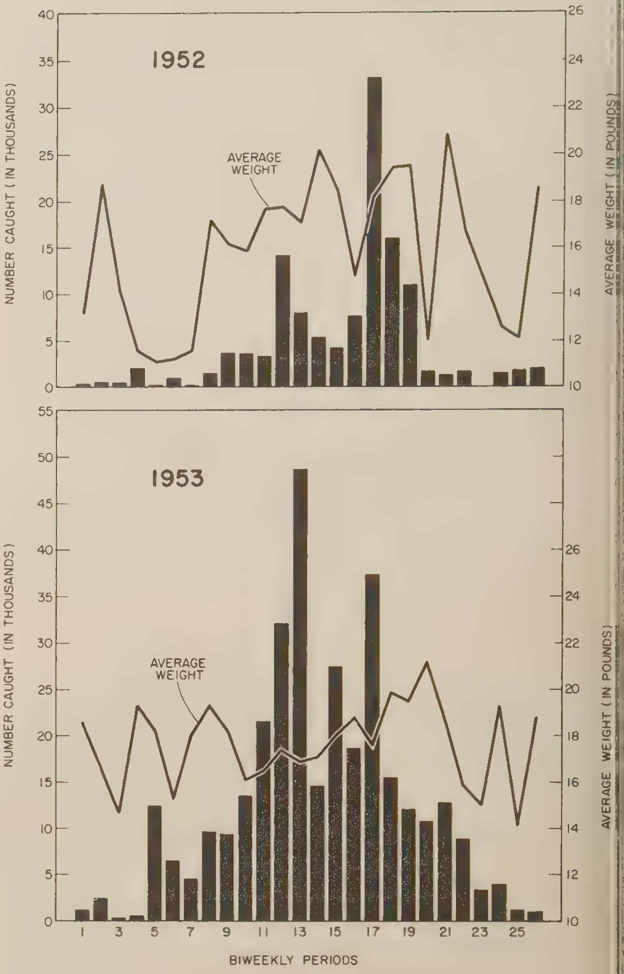


FIGURE 12.—Catch of large skipjack in the Oahu region, 1952 and 1953.

Period 5 of 1953, with its unusual numbers of very large fish, must consist of skipjack greater in size than the 1953-season fish. It seems probable that these very large skipjack are 1952-season fish, which were present only briefly that year. The relatively high average weights during other periods of early 1953 imply that 1952-season fish may have been generally present during that time. In early 1952, on the other hand, few of the previous year's season fish were present, as judged by the average weights during periods 4 to 7.

---

[1] Conversions of length (millimeters) to weigh (pounds) were made according to the formula: Log weight$=-8.2755+3.34913$ log total length.

Size Composition

Small skipjack are usually sought by the fishermen only when they are unable to locate larger fish. One would expect, therefore, that the occurrence of small fish in the catch would be inversely related to the presence of the larger skipjack, and this does seem to be the situation. The numbers of large and small skipjack taken in the Oahu fishery in each biweekly period of the 2 years under study is plotted in figure 13. In 28 biweekly periods (1952, 8–20; 1953, 8–22) when large skipjack were generally present, a tabulation was made to see how frequently the changes in the number of one size group were associated with similar or opposite changes in the other. Opposite trends, e.g., the number of large skipjack decreases from the preceding period while the number of small skipjack increases, occur in 22 periods while similar trends occur in 6. The probability of obtaining such a distribution if the numbers of large and small fish in the catch fluctuate independently of one another is less than 0.01.

Size composition appears to be important in the determination of the general level of catch (fig. 14) and the pounds caught per unit-of-effort (fig. 15). Both increase rapidly with an increasing proportion of large fish up to a ratio of 1 large fish for 1 small fish. Above this ratio the total catch continues to increase at a fairly rapid rate, but catch per unit of effort increases at a slower rate.

The likelihood of catches of large numbers of individuals seems to be loosely linked with the size composition. During the interval included in this study, the largest numbers of skipjack were taken either when small fish were especially numerous and very few large fish were available or when large skipjack were in a majority (fig. 16). When small fish outnumber the large, but are less than 10 times as numerous, there seem to be factors that work against the capture of a large number of individuals. These factors, if they exist, are probably related to the distribution of the various size groups in the population which supports the fishery. A hypothesis concerning the structure of this population is offered below.

Conjecture

In order to account for the variations in apparent abundance of particular size groups in the catches, it is necessary to hypothesize a skipjack population consisting of at least three and possibly one additional element. In the approximate order of their importance to the success of the fishery in 1952–53, these are as follows:

Group A: "Season fish," approximately 17–22 pounds in weight, which Brock assumes to be in either their second or third year of life. This group is migratory.

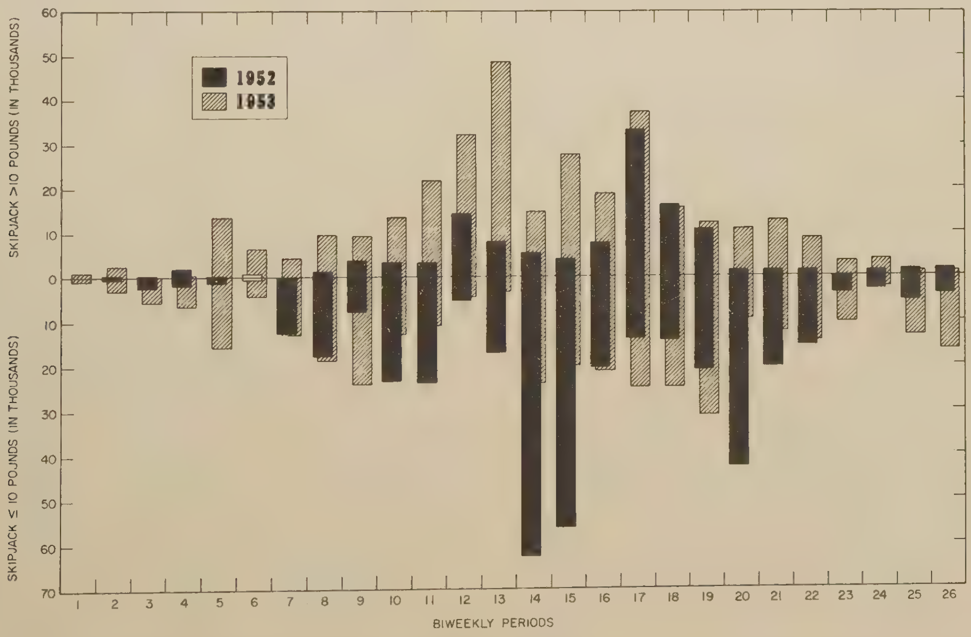


Figure 13.—Estimated numbers of large and small skipjack taken in the Oahu fishery, 1952–53, by biweekly periods.

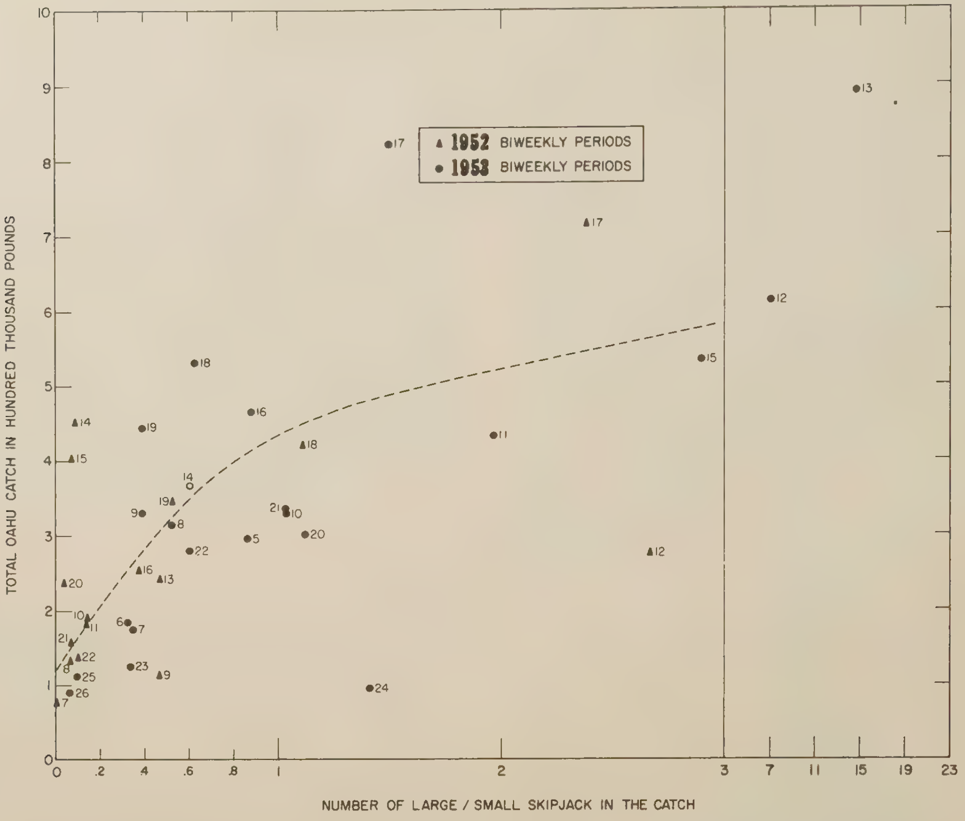


FIGURE 14.—Size composition and the total catch in the Oahu skipjack fishery, 1952–53.

Group B: Nonmigratory small fish, which during the summer months are about 4 to 8 pounds in weight. These fish occur in semi-permanent aggregations which are to be found in certain localities, usually near shore, where presumably oceanographic conditions are suitable for the concentration of food organisms. These fish, according to Brock's hypothesis, are a year younger than the season fish. This group serves as the main source of supply for some of the fishermen, but in general it functions as a reserve supply where most of the fishermen can use their bait, when larger fish are not available.

Group C: Large migratory skipjack, 28–32 pounds, which may be a year older than the season fish. This group seems to have been abundant during the first part of 1953 and accounts for the apparent early begining of the season in that year.

Group D: Migratory small skipjack. The existence of this group is not well established; however, the large numbers of small fish which appear suddenly in the fishery in periods 14, 15, and 20 of 1952 suggests that there may be a migratory group of small fish as well as the semiresident group.

In figure 16, catches of large skipjack numbering in excess of 15,000 were all made when season fish (group A) were apparently dominant in the fishery; the large catches of small skipjack, those in excess of 40,000, are presumed to result from the presence of migratory small fish (group D). The sharp decline in the number of periods with catches of small skipjack greater than 25,000 may indicate that this number is about the maximum number of nonmigratory fish (group B), which are available during a biweekly period. Except for period 17, 1953, the number of small fish in the catch declines as the number of large fish increases, which is consistent with the assumption that the number of small fish caught is inversely related to the availability of large fish. The extra-large migratory fish (group C) are distinguished by their greater average weight relative to the season fish, and not, at least during 1952–53, by their unusually large numbers. At the time of

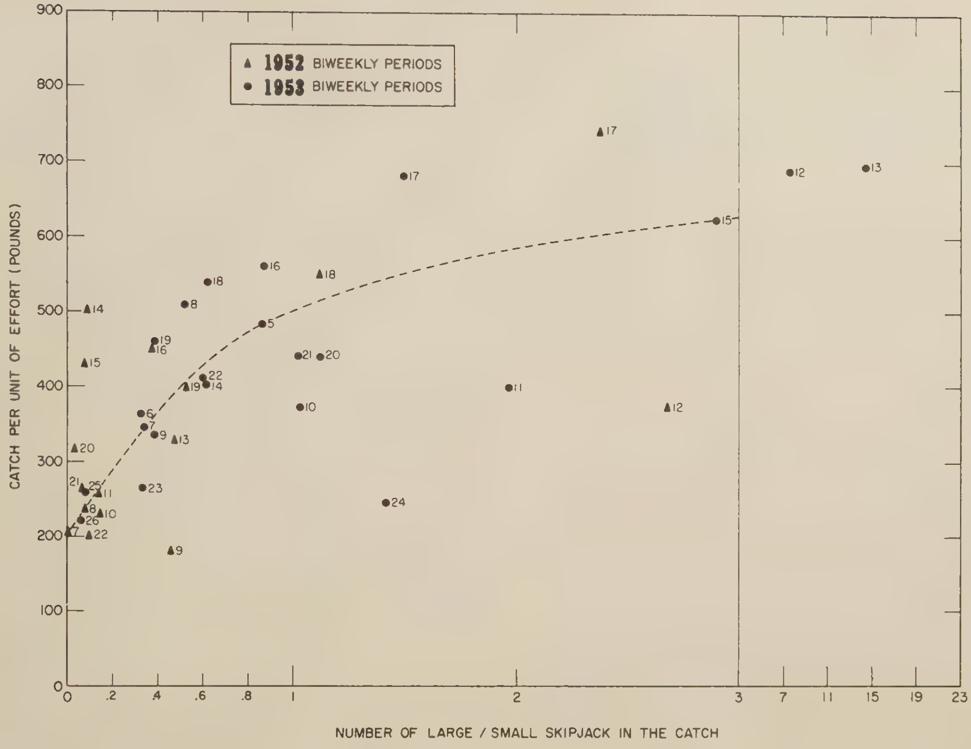
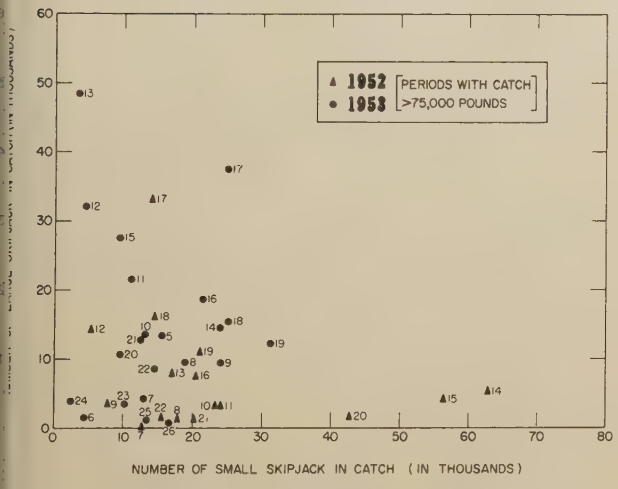


FIGURE 15.—Size composition and catch per unit-of-effort in the Oahu skipjack fishery, 1952–53.



IGURE 16.—Size composition and the number of skipjack caught in the Oahu fishery, 1952–53.

heir appearance in the catch during periods 5 and –9, 1953 (fig. 12), they were associated with fairly arge numbers of the nonmigratory small fish.

The fact that the three migratory groups seem o occur at different times suggests that there is ittle overlap in their distribution, but the catch ecords do not show this with certainty, for (see Sources of Error) the average weight of fish in the catch is a none too adequate index of size composition. The actual distribution of small skipjack is not defined by their appearance in the catch. It is possible that during the periods when the catch consists predominantly of large fish, small skipjack are also available, but have been rejected by the fishermen. In order to obtain information as to the quantity of small fish actually present, a method such as maintenance of logbooks in which the fishermen could record their observations of all fish sighted, whether fished or not, would be required.

The catch records provide little means of determining the relations between the four groups of skipjack which seem to make up the population exploited by the Hawaii fishery. It is quite probable that the small fish in both the migratory and semiresident groups furnish recruits for the season fish. The season fish of a given year may be the large fish of the next year. The long-term recovery of tagged specimens would appear to offer the best means of ascertaining the relations between these different groups of fish.

SUMMARY

1. The staff of the Honolulu Biological Laboratory is trying to determine the environmental conditions which influence the local availability of skipjack. Commercial catch records are a source of information.

2. Methods and sources of error are considered. Fish catch reports for 1952 (a poor year) and 1953 (a good year) were summarized by areas of the fishery and biweekly fishing periods. The unit of fishing effort, the productive fisherman-trip, is discussed.

3. The distribution of catches and effort in the 2 years was generally similar, with leeward Oahu contributing one-half the catch. Hawaii, windward Oahu, and Kauai fell well below leeward Oahu in productivity, while Maui and the oceanic region contributed insignificant proprotions.

4. Pounds caught per unit of effort increased from southeast to northwest in the fishery and from inshore to offshore, but these trends may result from differences in the fishery rather than to distribution of fish.

5. There was a positive correlation between the average weight per skipjack caught in various zones of the fishery and catch per unit of effort.

6. Catches (in pounds) during the fishing periods of 1953 were, with few exceptions, larger than those made during the corresponding periods of 1952.

7. In comparison with the seasonal trend in the fishery, the effects of rough weather (as indicated by periods of small craft warnings), were unimportant.

8. Large skipjack, from their appearance in the catches, seemed to have arrived first in leeward areas, and at the end of the season they last appeared in catches from leeward areas. In June and August of both years, concentrations of season fish occurred in windward Oahu and leeward Oahu, respectively.

9. The numbers of small fish taken by the Oahu fishery in 1952 and 1953 were approximately equal, but almost three times as many large fish were caught in 1953. In the Oahu region, there was almost one and one-half times the fishing effort in 1953 in comparison with 1952, and a much larger proportion was directed toward catching large skipjack.

10. Catch, effort and catch per unit of effort indexes have similar seasonal variations. The positive correlation between catch and catch per unit-of-effort is so close that there is little to be gained in using the catch per unit-of-effort as an index of apparent abundance in the fishery.

11. During the middle of 1953, the average weight of large skipjack increased at 0.25 pound per week, the growth rate for Hawaii skipjack estimated by Brock. This suggests that fish of the same age were constantly available to the fishery during this period.

12. The number of small skipjack in the catch varied inversely with the number of large fish.

13. A hypothesis for the structure of the skipjack population supporting the fishery is offered. The population has four groups: (1) season fish and (2) extra-large fish, both of which are migratory, and (3) a semiresident and (4) a migratory group of smaller skipjack.

LITERATURE CITED

Brock, V. E.
1954. Some aspects of the biology of the aku, *Katsuwonus pelamis*, in the Hawaiian Islands. Pacific Science 8(1) : p. 94–104.

June, F. C.
1951. Preliminary fisheries survey of the Hawaiian-Line Islands area. Part III. The live-bait skipjack fishery of the Hawaiian Islands. U.S. Fish and Wildlife Service, Commercial Fisheries Review 13(2) : p. 1–18.

Kendall, M. G.
1951. The advanced theory of statistics. Vol. II. Third edition. Charles Griffin & Co., Ltd., London, England. 521 p.

Royce, W. F., and T. Otsu.
1955. Observation of skipjack schools in Hawaiian waters, 1953. U.S. Fish and Wildlife Service, Special Scientific Report—Fisheries No. 147, 31 p.

Snedecor, G. W.
1956. Statistical methods, 5th edition. The Iowa State College Press, Ames, Iowa. 534 p.

Yamashita, D. T.
1958. Analysis of catch statistics of the Hawaiian skipjack fishery. U.S. Fish and Wildlife Service, Fishery Bulletin 134, vol. 58, p. 253–278.

Yuen, H. S. H.
1959. Variability of skipjack response to live bait. U.S. Fish and Wildlife Service, Fishery Bulletin 160, vol. 60, p. 87–106.

U. S. GOVERNMENT PRINTING OFFICE : 1962 O - 596560

DISPLAY COPY

Records of the Genetics Society of America, number 30, p. 111. (Abstract),
Also in Genetics, volume 46, number 8, p. 981.

Sprague, Lucian M., Bureau of Commercial Fisheries, Biological Laboratory, Honolulu, Hawaii: *Erythrocyte antigens of the oceanic skipjack (Katsuwonus pelamis) recognized by phytoagglutinins.*—Saline extracts of leguminous seeds often have the property of agglutinating vertebrate erythrocytes. While many species of legumes yield extracts which agglutinate the erythrocytes of skipjack, five species, *Maackia amurensis*, *Virgilia capensis*, *Caragana arborescens*, *Glycine max*, and *Phaseolus vulgaris*, produce fluids which will recognize individual differences between skipjack bloods by agglutination procedures. Maackia extracts agglutinate all skipjack tested but following absorption by selected cells a fraction remains which exhibits an identical reaction pattern in comparison with Virgilia extracts.—In tests of 642 skipjack with extracts of the above seeds, four distinct patterns of reaction have been observed. Virgilia and Caragana permit the recognition of three phenotypes. Bloods agglutinated by Virgilia fail to react with Caragana. Bloods agglutinated by Caragana fail to react with Virgilia. Some bloods fail to react with either extract.—The patterns detected by Glycine and Phaseolus are apparently independent of one another and the Virgilia and Caragana patterns.—The relative proportion of the phenotypes recognized by Virgilia-Caragana and by Glycine are significantly related to the geographic origin of the samples.—A continuing study of the relative proportion of phenotypes in samples from different geographic localities in the central North and South Pacific Ocean is being made in an attempt to relate racial groups with marine ecology. Acknowledgment is made to Professor Charles Cotterman for the initial samples of seed.

DISPLAY COPY

Abstracts of Symposium Papers, Tenth Pacific Science Congress, p. 186.

SYMPOSIUM ON IMMUNOGENETIC CONCEPTS
IN MARINE POPULATION RESEARCH

Studies on the Erythrocyte Antigens of the Skipjack Tuna (*Katsuwonus pelamis*)

LUCIAN M. SPRAGUE and LESLIE I. NAKASHIMA, U. S. Bureau of Commercial Fisheries, Honolulu Biological Laboratory, Honolulu, Hawaii, U. S. A.

At least five blood factors which form four systems of blood groups have been identified in the red blood cells of the skipjack tuna.

One, the C antigen, has been described by Cushing (1956). C-positive individuals are recognized by the action of natural bovine and ovine heteroagglutinins.

Four additional blood factors are now recognized by the use of saline extracts of legume seeds. Extracts of *Glycine max* detect A-positive bloods, extracts of *Phaseolus vulgaris* detect D-positive bloods, and extracts of *Virgilia divaricata* and *Caragana arborescens* detect two blood factors in the B system, Be and Bf. The relationships of Be Bf are not well understood except that they have mutually exclusive properties, Be-positive animals being Bf-negative and vice versa. About 20 to 30 per cent of the skipjack tested are Be-Bf-negative.

Of these reagents, those recognizing D-positive individuals and those recognizing Bf-positive individuals are not sufficiently definitive for use in population studies.

Reagents detecting C-positive, A-positive, and Be-positive animals, however, may be used to explicitly categorize skipjack erythrocytes. These reagents have been used in tests of 688 skipjack from the islands or island systems of Hawaii, Johnson, Christmas, Marquesas, and Rangiroa (Tuamotus).

When the frequencies of the occurrence of Be individuals from these areas were compared, the relative proportion of Be individuals sampled near Rangiroa was clearly distinct from the frequencies of Be from all other areas sampled ($P < .001$; *z*-test).

The sample from the Marquesas Islands is different from all other areas with respect to the frequency of the occurrence of C-positive individuals ($.05 < P < .01$; *z*-test).

On the contrary, samples taken from Hawaii, Christmas, and Johnson Islands exhibit marked homogeneity in the frequencies of the characters A,C, and Be. These data indicate the occurrence of at least two reproductively isolated stocks of skipjack in the areas sampled.

Further studies are inprogress which will attempt to delineate the range and character of these stocks in greater detail.

DONALD W. STRASBURG

DIVING BEHAVIOUR OF HAWAIIAN SKIPJACK TUNA

EXTRAIT DU JOURNAL DU CONSEIL INTERNATIONAL
POUR L'EXPLORATION DE LA MER
VOL. XXVI. No. 2. 1961

Diving Behaviour of Hawaiian Skipjack Tuna

By

Donald W. Strasburg

Honolulu Biological Laboratory
U. S. Bureau of Commercial Fisheries, Honolulu, Hawaii*

Introduction

The principal commercial fishery in Hawaii is for oceanic skipjack, *Katsuwonus pelamis* (Linnaeus), a surface-schooling tuna 40–90 cm in length which is captured exclusively by day using pole-and-line with live-bait as chum. In an attempt to increase the catch per unit of effort, the Honolulu Biological Laboratory (HBL), U.S. Bureau of Commercial Fisheries, has begun studies of skipjack behaviour. Major aspects of this subject have been investigated from an underwater observation chamber mounted on the research vessel "Charles H. Gilbert". This blister-like structure, which has been described by STRASBURG and YUEN (1960), is located two metres below the surface in the fishing area at the ship's stern. From this vantage point it is possible to study skipjack behaviour during fishing and at other times.

During July–September 1959, the "Charles H. Gilbert" was engaged in experimental skipjack fishing in Hawaiian waters. Experiments consisted of varying certain fishing conditions such as kind and amount of bait, bait supplements, etc., and in addition to such tests, collecting general information on the behaviour of skipjack. One conspicuous behaviour pattern observed during skipjack fishing was an abrupt vertical movement which we have called "diving". Diving consisted of skipjack vanishing from view in a nearly vertical direction, the fish disappearing at 30–60 m depths. This is of practical importance to the fisherman, for a school which dives frequently requires more bait and yields a smaller catch than a school which remains at the surface.

This report describes a possible cause of skipjack diving. Attention was focused on prey organisms because preliminary observations indicated a relation between prey and behaviour. For example, the fishermen believe that skipjack are conditioned to their natural food, and are difficult to catch with baits differing greatly from this food. In order to evaluate the feasibility of fishing a particular school they examine the spewings of the first few fish caught. The results of their examinations may be used to determine fishing procedure

---

* Published by permission of the Director, U. S. Bureau of Commercial Fisheries.

or to rationalize a poor catch. If the regurgitated material contains numerous postlarval synodontid fish, the fishermen believe that few skipjack will be caught and extensive bait expenditure is unwarranted.

Methods

Test fishing on the "Charles H. Gilbert" consisted of alternate periods of normal and experimental routine which allowed observers to compare skipjack behaviour under constrasting conditions. Although frequently affecting catch and catch rate, none of the tests caused the tuna to dive, and test effects are therefore ignored in the following account. Records of tuna activity consisted of underwater motion pictures, recorded oral comments by underwater and surface observers, and records of time and catch. Echo-sounders were not used to record skipjack activity primarily because these fish lack a swim-bladder and thus give poor echoes. After fishing, meteorological and water temperature data were obtained, and a sample of the catch was examined for length, sex, and food consumed.

Stomach contents were usually determined for a sample of ten skipjack, but a larger number was examined when an unusual diet was indicated. Dietary items were counted and a rough attempt made to judge their volumes. Excluding bait, 42 food items were encountered, but only ten of these occurred frequently. One of these, unidentified fish remains, was not considered further, but an idea of the importance of the others can be obtained from Table 1.

Identification of the more important food items was necessarily based on the specimens in best condition, and there is a possibility that other species occurred in the damaged material. Fish being eaten were postlarval *Acanthurus* spp. (Acanthuridae), postlarval *Chaetodon corallicola* Snyder (Chaetodontidae), juvenile *Holocentrus lacteoguttatus* Cuvier and Valenciennes (Holocentridae), juvenile *Parupeneus* sp. (Mullidae), and postlarval *Synodus variegatus* (Lacepède) (Synodontidae). Because these fish are littoral as adults, some interest is attached to the fact that their larval and juvenile stages are pelagic. It is thus desirable to explain the procedures used in identification and to briefly describe the specimens.

Acronurus-stage Acanthuridae were identified with the aid of RANDALL's publications (1955, 1956). Meristic characters were used to determine the silvery 25–33 mm chaetodontid postlarvae. Their formulae of dorsal rays XIII, 21 to 23 (usually 22); anal rays III, 18 or 19; pectoral rays 15; and scale rows 31 to 33 are referable only to *Chaetodon corallicola* among the Hawaiian butterfly fishes (GOSLINE and BROCK, 1960; WOODS, in SCHULTZ, *et al.*, 1953; and personal examination of specimens). The squirrel fish were all *Holocentrus lacteoguttatus* (WOODS, in SCHULTZ, *et al.*, 1953; GOSLINE and BROCK, 1960); they were 54–58 mm in standard length, deep blue dorsally, silvery ventrally, and with a bright violet stripe separating these colours. The mullids were also blue and silver, and 53–58 mm in standard length. Four preserved mullids had a single row of caniniform teeth in each jaw and $2-\frac{1}{2}$ scale rows between the lateral line and the dorsal fin interspace. According to GOSLINE and BROCK (1960) they are therefore a species of *Parupeneus*. The descriptions by GIBBS (1959), GOSLINE and BROCK (1960), and SCHULTZ (in SCHULTZ, *et al.*, 1953) were used to identify synodontid postlarvae. The deep-lying dark spots as well as the

Table 1

Diet versus dive-frequency in skipjack

Station number	Number of dives		Number of skipjack eating item (adjusted to sample size 10)								
	Dives ≥ 1 min.	All dives	Acanthuridae	Chaetodontidae	Holocentridae	Mullidae	Synodontidae	Crab megalops	Squid	Stomatopods	Empty
45– 2	0	0	0	0	0	7	0	0	1	0	0
– 3	3	5	0	5·4	0	10	0	4·6	2·3	0·8	0
– 7	1	4	2	10	1	6	0	9	1	1	0
– 8	0	2	1	2	0	0	0	0	5	2	2
– 9	0	0	2	6	0	1	0	0	1	0	0
–23	3	3	0	5	0	0	0	0	0	1	2
–32	1	4	2	1	0	6	1	0	0	0	2
–33	1	2	6	9	1	1	2	1	9	4	1
–34	0	2	2	5	0	4	0	1	2	0	0
–35	1	3	6	10	3	6	2	0	6	4	0
–37	0	1	0	10	0	0	0	2	1·3	0·7	0
–38	1	1	0	10	0	0	1	0	0	1	0
–39	1	5	1	10	0	0	0	3	2	2	0
–44	1	2	1	5	0	2	0	1	3	1	2
–46	2	3	0	3·1	0·8	0	3·8	0	4·6	0·8	0·8
–47	1	1	0	0	0	4	0	0	3	0	5
–49	0	1	0	5	2	0	0	0	4	4	1
–50	5	7	0	2	3	0	4	0	8	0	0
–54	1	1	1	2	2	10	1	0	4	3	0
–57	0	1	1·2	0	0	0·6	0·6	5	1·9	8·8	0
–58	3	5	1	1	2	0	0	1	1	5	1
–59	1	3	0	0·7	3	9·3	0	0	0·7	0	0·7
46– 7	1	1	1·7	0	0	0	0	0	3·3	0·6	4·4
–10	6	8	2	0	9	1	2	0	5	1	0
r, all dives			0·036	–0·061	0·622[2]	–0·020	0·426[1]	0·160	0·242	–0·093	–0·228
r, dives ≥ 1 min. .			–0·089	–0·233	0·681[2]	–0·101	0·518[2]	–0·089	0·294	–0·046	–0·087
% of stomachs containing item (305 stomachs examined)			10·5	36·7	9·8	27·5	6·6	10·8	27·9	17·4	12·1
% of schools eating item (27 schools sampled)			51·9	74·1	44·4	55·6	37·0	33·3	85·2	70·4	48·1

[1] Indicates a *p*-value between 0·05 and 0·01. [2] Indicates a *p*-value less than 0·01.

dentition of tongue and jaws showed the 12 preserved specimens to be *Synodus*; one specimen, at least, had the dorsal fin formula of *S. variegatus*. These postlarval lizardfish were large, 55–62 mm in standard length, and were eaten by skipjack captured 3–16 km from shore.

No attempt was made to identify the crabs megalops or stomatopods, but the squid were examined by Robert T. B. Iversen of HBL and identified as *Symplectoteuthis oualaniensis* (Lesson) and *Ommastrephes* sp., both of the family Ommastrephidae.

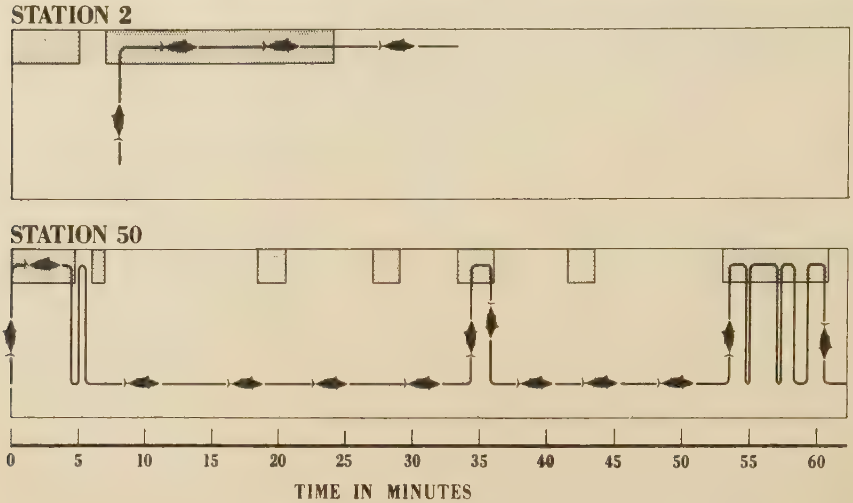


Figure 1. Activity of non-diving and diving schools of skipjack during fishing. Shaded blocks represent chumming intervals, fish figures indicate skipjack activity (surfacing or diving) during this period.

Relation of Diet to Diving

In the most desirable fishing situation a school of skipjack was attracted to the stern with live-bait (attracting fish with live-bait is locally known as chumming) and held there continuously for varying periods of time, usually about 20–30 minutes. With a diving school, the tuna were not only difficult to attract, but after fishing had begun it was periodically interrupted by the fish disappearing into the depths. Diagrammatic representations of extreme cases of these patterns of activity are given in Figure 1. Similar diagrams were prepared for all 24 schools observed in detail, and from these the number of dives per school was determined. A school which remained at the surface until the end of fishing was not considered to have dived, even though it departed in a dive after chumming stopped. Schools leaving the fishing area horizontally were also not considered to have dived, even if they emerged from the depths when re-engaged.

It was evident that diving was the rule rather than the exception (Figure 2). The number of dives per school ranged from 0 to 8, with a mean of 2·7. The tuna were away from the surface as briefly as 3 seconds or as long as 28 minutes. In the case of prolonged dives it was impossible to be certain that only one school was involved. It was felt, however, that only one was present, for the ship remained in the same spot and there were no indications (by birds or surface disturbance) of the approach of other fish. Thirty-three of the 65 dives observed resulted in a surface absence of one minute or more. Most dives were vertical or nearly so, and frequently the fish passed beneath the vessel as they descended. In nearly all cases diving was simultaneous among the hundred or more skipjack visible from the observation chamber.

As explained above, a sample of ten stomachs per school was examined for food. A few larger samples were proportionately reduced to ten for the sake of

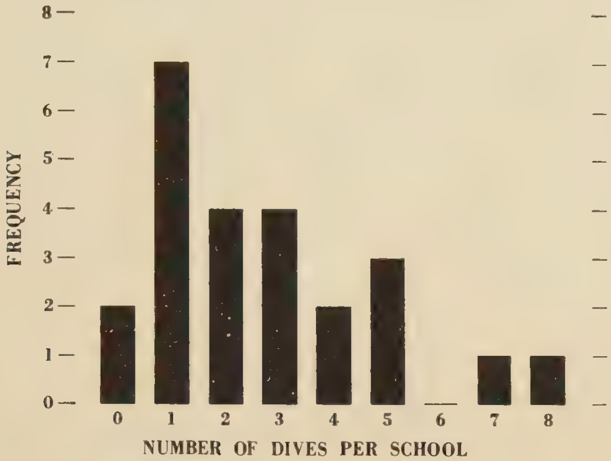


Figure 2. Frequency of diving in Hawaiian skipjack schools.

uniformity. The basic data, together with the results of the correlation analyses used to relate diet and dive-frequency are presented in Table 1. From this it is clear that the consumption of two foods, postlarval *Synodus variegatus* and juvenile *Holocentrus lacteoguttatus*, was significantly related to diving frequency. The correlation analyses treat each food item as if only it had been eaten, and therefore no particular account is taken of those cases, indicated in Table 1, in which *Synodus* and *Holocentrus* occurred together in skipjack stomachs.

Discussion

The food habits of Hawaiian skipjack have been discussed by WELSH (1949) and YUEN (1959), and are generally the same as those of skipjack of Japan (SUYEHIRO, 1938; HOTTA and OGAWA, 1955) and the Philippines (RONQUILLO, 1953). Wherever they occur, skipjack prey on small fish, squid, and crustaceans, taking a wide variety of species but also gorging on a few abundant forms. The heterogeneity of their diet has prompted RONQUILLO (1953) to state: "These pelagic fishes are seemingly nonselective, that is, they are voracious eaters. They would eat any living organism available."

With such proclivities it is perhaps surprising to find skipjack behaviour influenced by a particular kind of prey. One example of this phenomenon is YUEN's observation (1959) that skipjack feeding on nomeids, thunnids, carangids, and gempylids (all relatively fast swimmers) are caught at a greater rate than skipjack preying on slower-swimming chaetodontids, scorpaenids, molids, and acanthurids. Similarly, skipjack feeding on nomeids, thunnids, and gempylids, but not carangids, are caught for a longer time interval than those eating the slower species.

Other observations on the susceptibility to capture of skipjack schools in relation to their natural food are less clear-cut with respect to diet-induced behaviour. SUYEHIRO (1938) found that skipjack preying on neritic organisms (mackerel, horse mackerel, spotted shrimp, amphipods, and crab larvae) were relatively difficult to capture, whereas those taking oceanic food (flying fish, squid, and schizopods) were more easily caught. He surmised that this difference resulted from the relative abundance of food in neritic versus oceanic situations, rather than from a differential response to the food organisms.

It is unlikely that the consumption, *per se*, of *Synodus* or *Holocentrus* produces dyspepsia causing skipjack to flee the surface. Instead it is reasonable to think of them as diving in pursuit of deep-swimming prey whose attractiveness is greater than that of the chum. Thus, a school which is difficult to engage initially could be feeding on an enticing natural food, and one which dives after fishing has begun might be responding to natural food, or to other feeding skipjack, beneath it.

If better use is to be made of chum it is worthwhile to examine the characteristics of attractive natural food. In gross aspect there is little to distinguish *Holocentrus* from *Parupeneus*, the specimens recovered being of the same size, shape, and colour. They seem to have been equally available in 1959 (roughly half of the schools sampled had eaten each), although this is not always the case. YUEN (1959) found over three times as many schools eating holocentrids as mullids in 1956–57. Neither food seems to be preferred over the other, for although YUEN (unpublished data) found holocentrids in six times as many stomachs as mullids, the present data show holocentrids in one-third as many as mullids. Despite these vagaries, the fact remains that consumption of *Holocentrus* was associated with diving whereas consumption of *Parupeneus* was not. In addition to such possibilities as nonrandom sampling or a difference in the depth of occurrence of these two species, there is another possible explanation for this condition. This relates to prey behaviour, about which little is known, yet conceivably the "action" of *Holocentrus* might be attractive to skipjack whereas that of *Parupeneus* might not.

The other fish associated with diving, *Synodus variegatus*, is one of the few skipjack prey species having a prominent colour pattern. Whereas the other food organisms are inconspicuously colourless, blue, or silver, living *Synodus* postlarvae bear a series of large blackish spots on an otherwise unpigmented body. These markings are conspicuous to the human eye but do not suggest a fish-like form owing to the transparency of the intervening flesh. Instead an impression is given of an advancing file of disassociated spots. Judging from the dive data, skipjack detect and react to *Synodus* at distances on the order of 30 m. The immediacy of their response suggests triggering by some releaser, perhaps the spotted pattern of the prey. Apparently only a few *Synodus* are available to a skipjack school, for only 6·6 % of the stomachs examined in this study contained them, and YUEN (unpublished data) found them in only 10 of 573 stomachs. If these fish are as desirable skipjack food as they seem to be, then perhaps their characteristics can be put to human use. Mr. John C. MARR of HBL is presently examining the efficacy of skipjack lures having the shape and pattern of postlarval *Synodus*.

Summary

Observations from an underwater chamber showed that schools of skipjack commonly dive during fishing, leaving the surface for a minute or more on many occasions. Stomach analyses showed that the presence of two prey fish,

Synodus variegatus and *Holocentrus lacteoguttatus*, was significantly related to diving frequency. It was hypothesized that these two species were more attractive than the live-bait used by the fishermen, and that the skipjack dived in pursuit of them. A study of the characteristics of attractive natural food may lead to the development of better bait and lures for catching skipjack.

References

GIBBS, R. H., 1959. "A synopsis of the postlarvae of western Atlantic lizard-fishes (Synodontidae)." Copeia, 1959: 232–36.

GOSLINE, W. A., & BROCK, V. E., 1960. "Handbook of Hawaiian fishes." Univ. Hawaii Press, Honolulu, 372 pp.

HOTTA, H., & OGAWA, T., 1955. "On the stomach contents of the skipjack, *Katsuwonus pelamis*." Bull. Tohoku Reg. Fish. Res. Lab., **4**: 62–82.

RANDALL, J. E., 1955. "An analysis of the genera of surgeon fishes (family Acanthuridae)." Pacific Sci., **9**: 359–67.

RANDALL, J. E., 1956. "A revision of the surgeon fish genus *Acanthurus*." Pacific Sci., **10**: 159–235.

RONQUILLO, I. A., 1953. "Food habits of tunas and dolphins based upon the examination of their stomach contents." Philippine Jour. Fish., **2**: 71–83.

SCHULTZ, L. P., *et al.*, 1953. "Fishes of the Marshall and Marianas Islands." Bull. U. S. nat. Mus., No. 202, 685 pp.

STRASBURG, D. W., & YUEN, H. S. H., 1960. "Progress in observing tuna underwater at sea." J. Cons. int. Explor. Mer, **26**: 80–93.

SUYEHIRO, Y., 1938. "The study of finding the reasons why the bonito does not take to the angling-baits." J. Imp. Fish. Exper. Sta., **9** (69): 87–101.

WELSH, J. P., 1949. "A preliminary study of food and feeding habits of Hawaiian kawakawa, mahimahi, ono, aku and ahi." Terr. Hawaii Div. Fish & Game, Fish. Prog. Rept., **1** (2), 26 pp.

YUEN, H. S. H., 1959. "Variability of skipjack response to live-bait." Fish. Bull. U. S., **60**: 147–60.

ANDELSBOGTRYKKERIET I ODENSE

DISPLA

Reprinted from ATLANTIC NATURALIST
Copyright by the Audubon Naturalist Society
of the Central Atlantic States, Inc.
OCTOBER-DECEMBER, 1961

cost is so high, and I wonder if it could have been reduced if the many fine reproductions of colored photographs had been omitted. Similar ones are found in many other volumes and they are not used in this book specifically to illustrate points in the text.

Gordon M. Meade, M.D.

Herald, Earl S. LIVING FISHES OF THE WORLD. Doubleday & Co., Inc. Garden City, New York. 1961. Pp. 304. Illus. $12.50.

Living Fishes of the World is the sixth volume of the World of Nature Series, and like its predecessors, is handsomely illustrated, entertainingly written, and scientifically accurate. The plates in particular call for praise, for 145 of the more than 300 are in magnificent color, and all are prize examples of the photographer's art.

Aside from its pictorial beauty, *Living Fishes of the World* has much to recommend it. Nearly all of the important fish groups are illustrated and discussed in an appealing style, from the jawless hagfishes through the advanced anglerfishes, including the lobefins and lungfishes which have been termed living fossils. Nearly uniform emphasis is given to each family, so that the reader can become as familiar with rare fishes as with common forms. This tends to minimize the importance of certain speciose groups such as the Characidae, which, as the author notes, are thoroughly treated elsewhere. The salt water fishes have received most of the illustrations, a refreshing innovation considering that fresh water fish are much more easily photographed. The photographic treatment accorded the colorful and the bizarre might seem overly generous but is in keeping with the occurrence of these qualities in the fish world. There are anatomical diagrams, a glossary of the few technical terms employed, and a bibliography of fifty reference works.

In preparing his text, Dr. Herald has made extensive use of his experiences collecting and observing fish in many parts of the world and as Curator of the Steinhart Aquarium in San Francisco. The discussion of a typical family contains information on distribution, size, habits including diet and reproduction, method of capture, and commercial importance. To this basic framework are added interesting tidbits gleaned from a broad background of knowledge: how electric eels produce electricity, ideas on the poisonous nature of some snapper flesh, the circumstances of shark attacks, etc.

This book was not written for the professional ichthyologist, and technical jargon is at a minimum. Common names accompany the Latin names for nearly all fishes and fish groups. There are unfortunately several misspellings of Latin names, and two figures (*Trachinocephalus* and *Zebrasoma*) are misidentified. Its wealth of information and excellent illustrations make *Living Fishes of the World* a welcome addition to any library.

Donald W. Strasburg

Dr. Strasburg, a biologist with 6 years' experience in the Fish and Wildlife Services' Bureau of Commercial Fisheries, is now stationed at their Honolulu office.

Cochran, Doris M. LIVING AMPHIBIANS OF THE WORLD. Doubleday. 1961. Pp. 199. Illus. $12.50.

This is the seventh in the now well known series on "living" animals of the world. It has the usual handsome, large (8 1/2 by 11 inch) format, popular-style text covering all important amphibian groups, and a truly spectacular gallery of colored and black and white photographs.

Many who own the earlier volumes will be surprised that *Living Amphibians* has one-third fewer pages and roughly half as many illustrations in color as its predecessors. The price has not been reduced. They will also miss the informative, interpretive captions that added so much to the enjoyment of the extraordinary photographs in volumes such as Klots' *Living Insects* and Buchsbaum and Milne's *The Lower Animals.* In this work captions are brief; nothing more than identification and credits for most black and white pictures.

Many of the species of frogs and salamanders portrayed are more bold, bizarre, and colorful than naturalists, museum curators, and even zoo custodians would have believed. No zoo has

DISPLAY COPY

Reprinted from COPEIA, 1961, No. 4, pp. 478–480, Decemder 19
Printed in U. S. A.

LARVAL CARAPID FISHES FROM HAWAII, WITH REMARKS ON THE ECOLOGY OF ADULTS.—Midwater trawling ten miles off Waianae, Oahu, Hawaiian Islands, from the U. S. Bureau of Commercial Fisheries research vessel *Hugh M. Smith,* resulted in the capture of one vexillifer and two tenuis larval stages of the family Carapidae. The vexillifer is 64 mm in length and the tenuis 157 and 200 mm. Attempts to identify these larval pearlfish with their respective adult forms led to a brief examination of the biology of this family as represented in Hawaii.

Gosline and Brock (*Handbook of Hawaiian fishes, p. 280,* 1960) record *Snyderidia canina* Gilbert, *Encheliophis gracilis* (Bleeker), *Carapus margaritiferae* (Rendahl), and *Carapus homei* (Richardson) from Hawaii. Their material has been seen, with the exception of *Snyderidia,* along with additional adult specimens from the Bureau of Commercial Fisheries collections. Thanks are due Dr. W. A. Gosline, University of Hawaii, for the loan of his material, and Dr. D. C. Arnold, College of the Venerable Bede, for opinions on identification.

Page 479

With only four carapids known from Hawaii, the problem of relating the larval and adult stages was not particularly difficult. There is, however, the possibility of the larvae being the young of an unknown adult. The fact that the anal fin commenced anterior to the dorsal fin eliminated *Snyderidia* from consideration, while pectoral ray counts of 19–20 and anal ray counts of 196–241 eliminated *Carapus margaritiferae,* the adults of which have 13–14 pectoral and 161–163 anal rays. To determine whether the young were *E. gracilis* or *C. homei,* attention was turned to the morphology of the lower jaw, as illustrated by Arnold (*Bull. Brit. Mus. Nat. Hist. 4(6):256, 1956*). In *homei* the lower jaw is high posteriorly and bears a long bony ridge laterally, while in *gracilis* it is low posteriorly and lacks the ridge. My tenuis larvae have the jaw structure of *homei* and are referred to that species. That this is probably correct has been confirmed by D. C. Arnold (personal communication). The vexillifer, unfortunately, is damaged and cannot be identified as confidently. Its 203 anal rays fall within the 195–206 range found for adult *homei* rather than the 172–180 range found for adult *gracilis,* but it should be borne in mind that there is attrition of the tail tip in adults and these ranges may not be applicable to all size groups.

Fig. 1 shows the changes in gross morphology accompanying the transition from a pelagic to an inquiline mode of life for *C. homei.* Of note are the shrinkage in length, thickening in cross section, and increase in head size. A similar succession of events has been shown for *C. acus* by Padoa (*Pub. Staz. Zool. Napoli 20(2):111–21, 1947*).

Ecological data are available for the adults of three of the four species of Hawaiian Carapidae. Three *Encheliophis gracilis,* 192–237 mm in length, were obtained from the common sea cucumber, *Holothuria atra.* Two fish had gorged on the gonads of their hosts, the viscera of which were otherwise intact, while the third fish contained nothing in its stomach and was found in an eviscerated host. It appeared that the fish fed by swallowing the free ends of the attenuate gonad and working forward to the attached base. Parasitism on host gonads may be a general phenomenon for those species inhabiting holothurians, as it has been recorded for *Carapus acus* (Arnold, *Pub. Staz. Zool. Napoli 24(2): 160, 1953*). It cannot be a serious menace to the Hawaiian sea cucumber population, however, for *H. atra* is common on reefs whereas pearlfish are rare. Of 122 holothurians (114 *H. atra,* 4 *H. cinerascens,* and 4 *Actinopyga mauritiana*) dissected by the writer, only two contained fish. Dr. S. J. Townsley, University of Hawaii, has informed me that he found no pearlfish in 702 sea cucumbers palpated, but not dissected, in a search for commensal crabs. Of this total, 433 were *atra,* 208 were *mauritiana,* 8 were *cinerascens,* and the balance represented seven less common species. A similar paucity of pearlfish has been noted by Parker (*Proc. Nat. Acad. Sci. Wash. 12(7):421–2, 1926*) and Aronson and Mosher (*Anat. Rec. 111(3):489, 1951*) for the Florida-Bahamas region.

Four *Carapus homei,* 80–121 mm in length, were removed from the body cavities of cushion stars, *Culcita novaeguineae.* In contrast to the hosts of *E. gracilis,* which were obtained at depths of 1–6 feet, the starfish harboring *C. homei* were collected at 40–70 feet. The starfish were not abundant and were not systematically sampled for pearlfish, but it was noted that two fish sometimes occupied the same starfish. The stomachs of these inquiline *homei* were empty. The tenuis and vexillifer larvae of *homei* mentioned above were captured within 450 feet of the surface in water 8000 feet deep, the time of day being 8–10 P.M. Thus, contrary to Arnold's statement (1956), these larvae were epipelagic rather than benthic.

Page 480

Four *Carapus margaritiferae,* 60–73 mm in

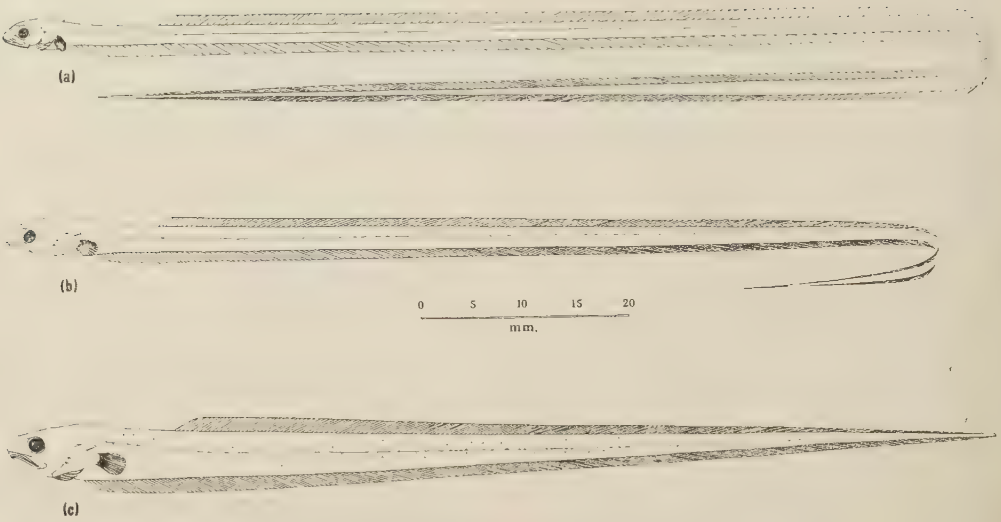


Fig. 1. Larval and juvenile stages of *Carapus homei*. (a) 200 mm. tenuis larva from high seas, (b) 120 mm. juvenile from *Culcita*, (c) 97 mm. juvenile from *Culcita*. The small protuberance anterior to the dorsal fin of the tenuis larva is the persistent vexillum base.

length, were available for study. One was found among the viscera of the rock oyster *Chama iostoma*, another from an unspecified oyster, and host data are not available for the other two. None contained food in the digestive tract, so that the diet of this remarkably toothed species remains unknown.—DONALD W. STRASBURG, *United States Department of the Interior, Bureau of Commercial Fisheries Biological Laboratory, Honolulu, Hawaii.*

DISPLAY COPY

Reprinted from COPEIA, 1961, No. 2, pp. 226–228, June 19
Printed in U. S. A.

BANDED COLOR PHASES OF TWO PELAGIC FISHES, *CORYPHAENA HIPPURUS* AND *KATSUWONUS PELAMIS*.—Banded color patterns in juveniles of pelagic fish species which do not, as adults, generally exhibit such patterns, have been recorded in the past, although not particularly commented upon. Observations of the last few years suggest that such patterns may also be common in the adults, but only while they are alive. Specifically, we wish to document the existence of banded color phases in living dolphin, *Coryphaena hippurus* Linnaeus 1758, and oceanic skipjack *Katsuwonus pelamis* (Linnaeus 1758).

One of us (Marr) observed banded dolphin off the west coast of Central America in the course of studies of the tropical tunas. An entry from his field notes for 17 March 1947 is: "At 0715 a small flock of boobies was seen working a school of bait. Upon approaching we could see a small school of bait. Larger fish breaking the surface slightly appeared to be dolphin (judging from their shape) but were banded; black bands alternating with greenish yellow ones! The bands were approximately 2" wide."

An entry of 11 April 1947 is: "At 0750 we came on a school of spinners [a species of porpoise] and yellowfin . . . We caught 252 yellowfin and three dolphin. One of the latter presented, while in the water, the same banded appearance previously noted. This was not discernible after the fish was brought aboard."

Both of these observations were made in the general area off Puntarenas, Costa Rica.

Two references to this phenomenon have been encountered in perhaps unconventional sources. One (Lamb and Cleveland, 1938. *Enchanted Vagabonds, p. 142*) relates to observations made in the general vicinity of Acapulco, Mexico: "Dolphins, to us, are the most beautiful fish in the sea. Their streamlined bodies are swift and graceful. They have a chameleon-like ability to change their color, turning from green to blue or brown, to yellow and brown stripes, their fighting colors."

The other (Hemingway, 1952. *The Old Man and the Sea, p. 79.*) refers to events in another ocean:

"I would like to fly very slowly at two hundred fathoms high and see the fish from above. In the turtle boats I was in the cross-trees of the mast-head and even at that height I saw much. The dolphin looked greener from there and you can see their stripes and their purple spots and you can see all of the school as they swim. Why is it that all the fast-moving fish of the dark current have purple backs and usually purple stripes or spots? The dolphin looks green of course because he is really golden. But when he comes to feed, truly hungry, purple stripes show in his sides as on a marlin. Can it be anger, or the greater speed he makes that brings them out?"

The other of us (Strasburg) has more recently had the opportunity to confirm the existence of this banded color phase in adult dolphin, and to extend our knowledge of its existence to adult oceanic skipjack. Observations of both species were made from an underwater viewing chamber, which has been described by Strasburg and Yuen (*J. Cons. Int. Explor. Mer*, In Press). This chamber is located near the stern of the U. S. Bureau of Commercial Fisheries' research vessel *Charles H. Gilbert*, and from it studies are being made of the feeding and schooling habits of pelagic fishes, principally Hawaiian skipjack. Motion pictures, still pictures and voice recordings provide the basis for subsequent analysis and also for the following account.

In July 1959, two large floating logs were encountered in Hawaiian waters, one a short distance off Waianae, Oahu, the other about 150 miles north of Nihoa. These logs were covered with sessile marine life and were closely accompanied by schools of small fish. Swimming around the logs were dolphin in surprisingly large numbers, 65 and 57 of which were ultimately landed after chumming with live bait. The length range of the captured dolphin was 620–1005 mm. More impressive than the number of dolphin was the variability of their color and color pattern. The ground color of various individuals was green, yellow, or silver, overlain with vertical bands or bars ranging from dark olive to black. In many individuals the bars were restricted to the head and trunk, the tail being the same color as the bars. In other fish, barring was uniformly distributed over the entire body, or sometimes completely lacking. A dolphin with at least three bars is shown in Fig. 1. Although difficult to detect from the photograph, the more anterior bars extend onto the dorsal fin membranes.

As noted above, the main use of the subsurface viewing chamber was for studying skipjack behavior, particularly their behavior during feeding. At such times large schools of skipjack were attracted to the ship's stern with live bait. Fig. 2 depicts a portion of such a school, and it is immediately apparent that skipjack, too, bear vertical bars. Bars were seen on fish weighing from 2 to over 30 pounds, but they were not always

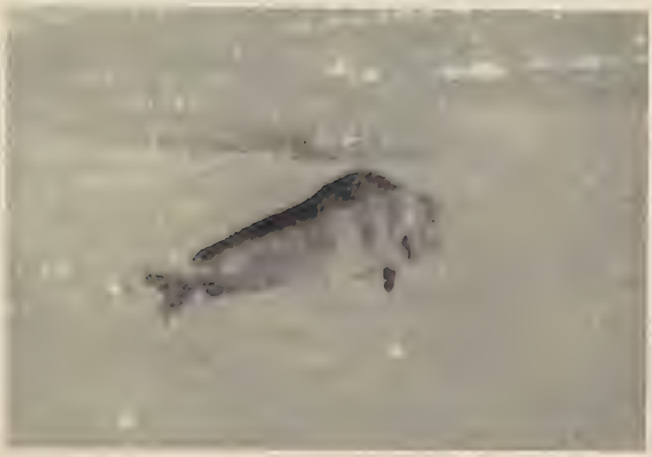


Fig. 1. Banded color phase of the dolphin, *Coryphaena hippurus*.

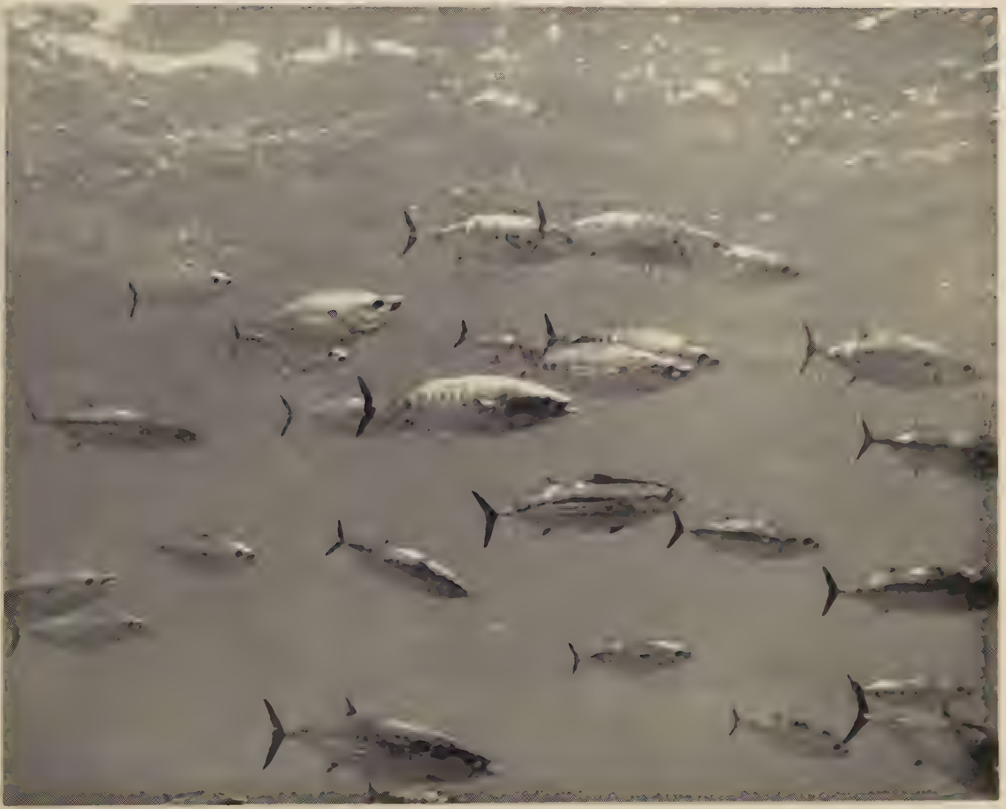


Fig. 2. School of oceanic skipjack, *Katsuwonus pelamis*, showing both vertical bars and horizontal stripes.

observed on all members of a school. The effect of the viewing angle on the visibility of the bars is not known, but it is apparent that the presence or absence of the bars was under nervous control. Hooked fish bore the marks only briefly after leaving the water and lost all vestiges of them when moribund.

It is apparent (see Fig. 2) that the persistent, dark horizontal stripes are interrupted by light vertical bars, while the light horizontal stripes are not interrupted by dark vertical bars. The transitory barred or banded appearance, then, is produced by light rather than dark bars. Presumably this is accomplished by the contraction of melanophores.

In addition to Hawaii, underwater observations were made of bars on skipjack in the Line Islands and off the west coast of Central America. It is likely that these marks are a regularly occurring feature which has not been recorded in photographs or paintings because of their evanescent nature and the general lack of underwater viewing facilities.

A cursory search of the literature and available photographs reveals that vertical bars are common among pelagic fishes. In addition to the ephemeral bands of adult *Coryphaena* and *Katsuwonus*, we note more or less permanent bars or bar-like rows of spots on adult *Neothunnus, Acanthocybium, Istiophorus, Makaira, Naucrates,* and *Ranzania,* and on juvenile *Coryphaena* and *Neothunnus,* among the more conspicuous pelagic forms. Because of the similarity in ecological position of most of these fishes, it is tempting to postulate an adaptive importance for the bars. To the submerged human eye they render the fish neither more nor less conspicuous, for the marks are only visible at short range, long after the fish has come into view. (When viewed from above the surface of the water they do, however, have the effect of presenting an unfamiliar pattern on a familiar silhouette, thus making sight identifications difficult). Whether bars have a communicative function between fish is a question to be answered only after more detailed observations than we have been able to make.—DONALD W. STRASBURG and JOHN C. MARR, *U. S. Bureau of Commercial Fisheries, Honolulu, Hawaii.*

DISPLAY COPY

Hermaphroditic Skipjack

RICHARD N. UCHIDA

Reprinted from PACIFIC SCIENCE
April, 1961

Reprinted from PACIFIC SCIENCE, *vol. XV, no. 2, April, 1961*

Hermaphroditic Skipjack[1]

RICHARD N. UCHIDA[2]

TWO PAIRS of skipjack (*Katsuwonus pelamis*) gonads, each having male and female components, have come to my attention in the past 3 years. The first was received from Mr. Thomas S. Higa, proprietor of a Honolulu fish retail market, in April 1957. Mr. Higa recovered the gonads from a neighboring fish retailer who had discovered them in a freshly eviscerated 16-lb. skipjack. This fish was captured by the "Orion," a commercial skipjack vessel, on April 11, 1957, off Makua, Oahu, from a school of 15- to 18-lb. skipjack.

The ovo-testes (Fig. 1) were typically paired and elongate, joined posteriorly, and weighed 121 gm. (fresh weight). The male and female components were easily discernible. The left gonad was divided into three segments; the anterior one-sixth and posterior one-third were ovarian and the remainder testicular. The right gonad was divided into two segments; about two-thirds of the anterior portion was testicular and the remainder ovarian. Figure 2 shows the length of each of these segments.

The cream-colored testicular sections were solid and somewhat flattened in cross-section, and did not seem to be atypical in any way. There was no running milt present, but their size suggested that they were in a rather advanced stage of maturity. All ovarian sections were pinkish, but differed in firmness. The posterior segments were hollow and flabby, with a ribbed internal cavity extending their entire length. The single anterior ovarian section was nearly round in cross-section and rather turgid.

Detailed examination of the ovo-testes was made after they had been preserved in 10 per cent formalin. The longitudinal duct of each testicular section could be followed posteriorly to the juncture of the testicular and ovarian segments, after which the ductus deferens became obscured in the network of blood vessels on the surface of the ovarian section. No openings of the ductus deferens were detected anywhere in the area of the urogenital sinus.

The two posterior ovarian sections were joined posteriorly by a single oviduct which opened into the urogenital orifice. No duct could be found in the single anterior ovarian segment.

Microscopic examination of the ova was made to determine their degree of maturity. The lumen of the anterior ovarian section was filled

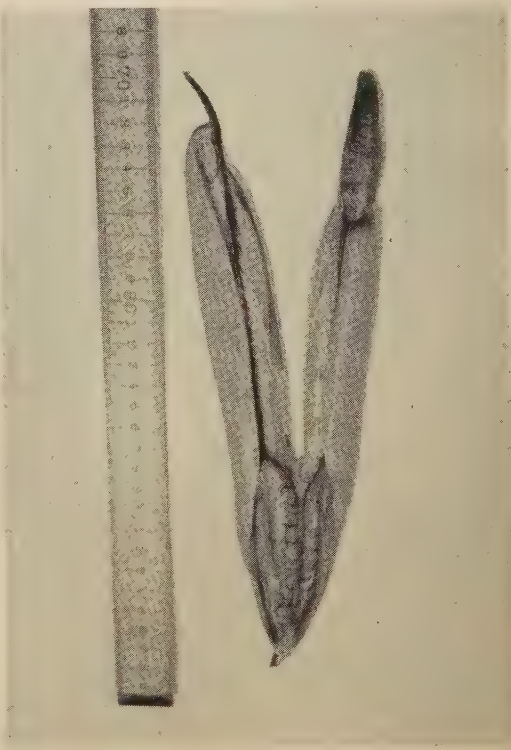


FIG. 1. The ovo-testes of a hermaphroditic skipjack (ventral view).

---

[1] Published with permission of the Director, U. S. Bureau of Commercial Fisheries. Manuscript received July 29, 1960.

[2] Fishery Research Biologist, Honolulu Biological Laboratory, U. S. Bureau of Commercial Fisheries, Honolulu, Hawaii.

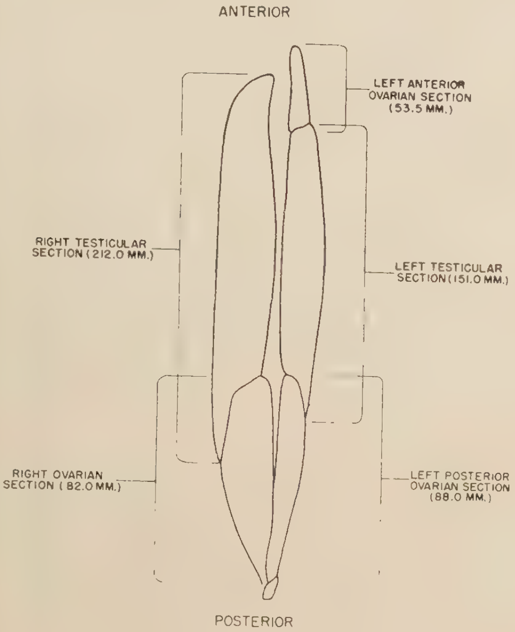

ANTERIOR
LEFT ANTERIOR OVARIAN SECTION (53.5 MM.)
RIGHT TESTICULAR SECTION (212.0 MM.)
LEFT TESTICULAR SECTION (151.0 MM.)
RIGHT OVARIAN SECTION (82.0 MM.)
LEFT POSTERIOR OVARIAN SECTION (88.0 MM.)
POSTERIOR

FIG. 2. Outline of the ovo-testes, showing the location and size of the male and female components (ventral view).

with a compact mass of resorbing ova, while the peripheral portion contained ova ranging from small, transparent stages to larger, opaque ova. The average diameter of 25 randomly selected larger, opaque ova was 0.504 mm. The posterior ovarian sections contained similar small and large ova, but no resorbing ova were present. Average diameters of randomly selected ova from these parts were 0.543 mm. for the left posterior member and 0.514 mm. for the right.

The presence of residual ova in the anterior section suggests that the fish had been a functional female. Assuming that the ova in each of the ovarian sections ripened at the same time, it is possible that ova were extruded from the posterior sections at spawning time, whereas ova in the anterior section could not be extruded because of the lack of an adequate duct. This could account for the presence of the resorbing ova in the lumen of the anterior ovarian section. Since the testicular sections were well developed and constituted a large part of the gonads, the fish may also have been a functional male.

The discovery of the second pair of ovo-testes was reported to the Honolulu Biological Laboratory on March 10, 1960, by Mr. Richard Nakashima of Honolulu, who found them in a 10-lb. skipjack.

The gonads, outlined in Figure 3 and labeled *A* and *B* for purpose of identification, were not joined posteriorly as a result of mutilation to both posterior ends during removal, and, therefore, could not be identified as to position (left or right). Both gonads were distinctly separated into three parts; an anterior ovarian section, a middle testicular portion, and a torn, fragmentary ovarian segment posteriorly. The testicular segments were similar to those found in the ovo-testes previously described, and contained no running milt. The ovarian sections were predominantly yellow with a tinge of pink. The anterior segments were flabby and hollow.

A starch suspension colored with powdered carmine was injected into the posterior ovarian section of gonad *A* and the flow of injected material indicated the presence of a duct connecting the two ovarian parts. A similar injection was attempted with gonad *B*, but failed

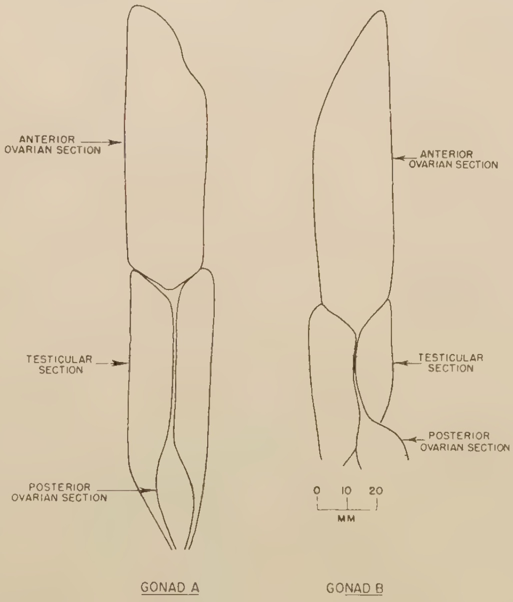

ANTERIOR OVARIAN SECTION
TESTICULAR SECTION
POSTERIOR OVARIAN SECTION
ANTERIOR OVARIAN SECTION
TESTICULAR SECTION
POSTERIOR OVARIAN SECTION
0 10 20
MM
GONAD A
GONAD B

FIG. 3. Outline of the ovo-testes, showing the location and relative size of the male and female components.

to reveal any ducts owing to excessive tissue damage.

Ova diameter measurements revealed that the posterior ovarian section of gonad *A* and both ovarian segments of gonad *B* were identical in their degree of development. The ova ranged from small, primitive ova to larger, opaque ova. Average diameters of 25 randomly selected ova of the most advanced group were 0.479 mm. for the posterior ovarian section of gonad *A* and 0.476 mm. and 0.479 mm. for the anterior and posterior ovarian sections, respectively, of gonad *B*.

The development of the anterior ovarian section of gonad *A* was dissimilar to any of the sections previously examined. Its lumen contained a loose mass of large, ripe, resorbing ova, together with a few completely degenerated ova. The peripheral portion of the section contained only primitive ova. Those intermediate to the primitive and the large, resorbing ova were absent.

The presence of residual ova indicates that this fish also had been a functional female. Again, it is not clear whether the ova remnants were the unexpelled portions of a previous successful spawning or a group of ripe ova that were not expelled owing to the inadequacy of the duct. Damage to the posterior portions of both gonads made it impossible to determine whether the male ducts were connected to the exterior, but since the testicular segments were well developed, this fish may also have been a functional male.

Hermaphroditism in skipjack is an extremely rare occurrence. So far as is known, only one other example has been recorded and described (Nakamura, H., 1935, Trans. Nat. Hist. Soc. Formosa 25(141): 197–198; in Japanese).

DISPLAY COPY

Reprinted from Science, October 6, 1961, Vol. 134, No. 3484, pages 1011-1012

Copyright © 1961 by the American Association for the Advancement of Science

Bow Wave Riding of Dolphins

Abstract. Dolphins riding bow waves were observed through underwater viewing ports. The postures assumed by the dolphins show that they present their bodies rather than the ventral surfaces of their flukes to the propellant forces of the bow wave.

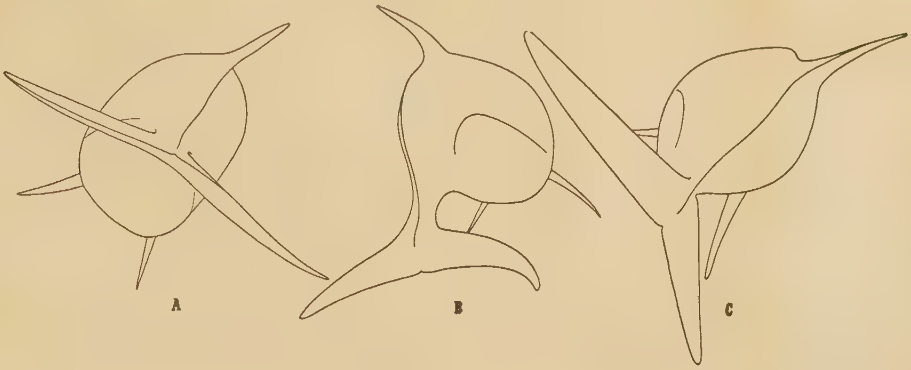


Fig. 2. Postures of *Tursiops* sp. while riding a bow wave.

How dolphins ride bow waves is the subject of a current controversy. After observing them performing this feat through underwater viewing ports in a ship's bow, I would like to report the method the dolphins themselves seem to consider proper.

Since Woodcock (*1*) noticed the "motionless" swimming of dolphins and interpreted it as bow wave riding, several proposals attempting to reconcile it with hydrodynamic theory have been advanced. Woodcock and McBride (*2*) concluded that only under conditions of laminar flow and nonbuoyancy could a dolphin sufficiently overcome drag to get a ride. Hayes (*3*) then showed in a terse presentation of calculations of hydrodynamic forces that the buoyancy of a dolphin in a pressure gradient determined the amount of hydrodynamic lift needed but did not affect the drag. Approaching the problem experimentally, Scholander (*4*) concluded that the tail flukes of a dolphin in the incline of a bow wave and properly angled up into the incline would be subject to enough force to push the whole animal forward. Objections by Hayes (*5*) to Scholander's hypothesis and a rebuttal by Scholander (*6*) were printed in *Science*. A point in disagreement was whether the forward component of the bow wave forces acted on the entire dolphin or just on its flukes. Fejer and Backus (*7*), stating that Hayes's explanation was correct but incomplete, supplied more observations on porpoises and computations on the nature of the pressure field and the function of ship's length and drag coefficient on the position of a wave-riding porpoise.

Underwater observation ports installed in the bow of the *Charles H. Gilbert* (Fig. 1)—research ship of the Bureau of Commercial Fisheries Biological Laboratory, Honolulu, Hawaii—in early 1960 for the purpose of studying tuna behavior provided excellent facilities for observing and photographing dolphins riding the bow wave. Since that time I have had occasion to observe several species of dolphins off the coast of northern California, off the coast of Mexico, and near Kingman Reef in the central equatorial Pacific. Motion pictures were successfully taken at the last location.

Porpoises did not always find the bow wave suitable for riding. When they first approached, they swam from side to side in front of the ship for a few minutes, apparently testing the pressure field, before they engaged in wave riding or left.

The field observations and reviews of the movie show that the dolphins assume several attitudes. The range of postures they assumed while riding the bow wave of the ship, which traveled at about 9 knots is shown in the outline drawings taken directly from the film (Fig. 2). The posture shown in Fig. *2B* is the one most commonly seen. The trailing edge of the flukes was an estimated ½ to 3 feet ahead of bow. The position and predominant posture of the dolphins indicate that their bodies are used to take advantage of the forward component of the forces of the bow wave. Moreover, they were never seen riding with their flukes angled in conformance with Scholander's hypothesis. The flukes seemed to be used solely to control hydrodynamic lift.

Although the dolphins often rode steadily, without changing their positions relative to the bow wave, they seem to prefer weaving laterally in and out among each other. In doing so they continually changed their vertical positions by as much as 3 feet and thus exhibited excellent control of hydro-

bending their bodies, and banking. Implied in Hayes's explanation is the necessity of lift control to enable the dolphins to meet exigencies caused by buoyancy changes. Therefore, although such control was postulated (*6*, *8*) to support Scholander's hypothesis, this assumption also supports Hayes's explanation (*9*).

HEENY S. H. YUEN
U.S. Department of the Interior,
Bureau of Commercial Fisheries
Biological Laboratory,
Honolulu, Hawaii

References and Notes

1. A. H. Woodcock, *Nature* **161**, 602 (1948).
2. ———, and A. F. McBride, *J. Exptl. Biol.* **28**, 215 (1951).
3. W. D. Hayes, *Nature* **172**, 1060 (1953).
4. P. F. Scholander, *Science* **129**, 1085 (1959).
5. W. D. Hayes, *ibid.* **130**, 1657 (1959).
6. P. F. Scholander, *ibid.* **130**, 1658 (1959).
7. A. A. Fejer and R. H. Backus, *Nature* **188**, 700 (1960).
8. M. S. Gordon, *Science* **133**, 204 (1961).
9. I wish to thank R. A. Barkley for clarifying some points in hydrodynamics. This report is published by permission of the director, U.S. Bureau of Commercial Fisheries.

1 May 1961

LIBRARY
BUREAU OF COMMERCIAL FISHERIES
FISH AND WILDLIFE SERVICE
P. O. BOX [illegible]
HONOLULU 12, HAWAII

LIBRARY
BUREAU OF COMMERCIAL FISHERIES
U. S. FISH AND WILDLIFE SERVICE
P. O. BOX 3830
HONOLULU 12, HAWAII